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Irrigated Spring Wheat

Production Guide for Southern Idaho

Editors
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Cooperative Extension Service
University of Idaho
College of Agriculture

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Chemical Disclaimer

Use of chemical names and trade names does not imply endorsement of named chemicals. These references are for comparison only.

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Basic Recommendations

- Use rotations and cultural practices that minimize weed, disease and insect problems and reduce the necessity for chemical controls.
- Plant early to avoid stress periods. Periodic field inspections detect problems before significant losses have occurred.
- Select varieties with appropriate disease resistance and maturity characteristics.
- Always use certified seed to assure seed purity and viability.
- Test soil to determine exact fertilizer requirements. Avoid over-fertilizing, particularly with nitrogen.
- Midsummer moisture stress conditions will limit spring wheat yields. Schedule irrigation to maintain 50 percent or greater available soil moisture for most growth periods. Schedule irrigation to maintain 60 percent or greater available soil moisture during tillering and boot to flowering.

Spring wheat is an important crop to Idaho, particularly in the irrigated regions of the Snake River Plain stretching from the Oregon to Wyoming borders. Irrigated spring wheat produced along the Snake River and its tributaries in southern Idaho typically accounts for 25 percent of all wheat and 75 percent of all spring wheat produced in the state. In 1987, 22.8 million bushels of spring wheat were grown on 265,000 irrigated acres in 32 counties across southern Idaho. All market classes of spring wheat are grown in this area. Profitable production of irrigated spring wheat requires consideration of all associated risks. The purpose of this publication is to summarize best management practices for irrigated spring wheat production in southern Idaho.

Spring Wheat Growth and Development

Irrigated spring wheat production requires a knowledge of crop growth and development. Cultural practices and environmental factors influence crop development. The application of fertilizer, pesticides, plant growth regulators and supplemental irrigati on should be based on stage of crop development rather than calendar dates. Improper timing of such operations reduces their effectiveness and can result in crop injury and yield loss. Crop growth rates depend on variety selection, accumulated heat units and nutrient and moisture availability. Spring wheat growth and development and methods for estimating the growth stage of individual plants and whole fields are described in University of Idaho MS 118, *Growth Staging of Wheat, Barley and Wild Oat.*

The development and growth of cereal grains have been translated into several numeric scales to quantify development for scientific and management purposes. Chemical companies are adopting these scales as a means of specifying proper application times for certain products. Three of these scales, Zadoks, Feekes and Haun, are described in Table 1. Feekes and Zadoks development scales are most commonly cited on product labels.

Table 1. Description of cereal grain development stages for Zadoks, Feekes and Haun scales.[1]

Zadoks Scale	Feekes Scale	Haun Scale	Description
			Germination
00			Dry seed
01			Start of imbibition
03			Imbibition complete
05			Radicle emerged from seed
07			Coleoptile emerged from seed
09		0.0	Leaf just at coleoptile tip
			Seedling growth
10	1		First leaf through coleoptile
11		1.+	First leaf unfolded
12		1.+	2 leaves unfolded
13		2.+	3 leaves unfolded
14		3.+	4 leaves unfolded
15		4.+	5 leaves unfolded
16		5.+	6 leaves unfolded
17		6.+	7 leaves unfolded
18		7.+	8 leaves unfolded
19			9 or more leaves unfolded
			Tillering
20			Main shoot only
21	2		Main shoot and 1 tiller
22			Main shoot and 2 tillers
23			Main shoot and 3 tillers
24			Main shoot and 4 tillers
25			Main shoot and 5 tillers
26	3		Main shoot and 6 tillers
27			Main shoot and 7 tillers
28			Main shoot and 8 tillers
29			Main shoot and 9 or more tillers
			Stem elongation
30	4-5		Pseudo stem erection
31	6		1st node detectable
32	7		2nd node detectable
33			3rd node detectable
34			4th node detectable
35			5th node detectable
36			6th node detectable
37	8		Flag leaf just visible
39	9		Flag leaf ligule/collar just visible

Zadoks Scale	Feekes Scale	Haun Scale	Description
			Booting
40			—
41		8-9	Flag leaf sheath extending
45	10	9.2	Boots just swollen
47			Flag leaf sheath opening
49		10.1	First awns visible
			Inflorescence Emergence
50	10.1	10.2	First spikelet of inflorescence visible
53	10.2		1/4 of inflorescence emerged
55	10.3	10.5	1/2 of inflorescence emerged
57	10.4	10.7	3/4 of inflorescence emerged
59	10.5	11.0	Emergence of inflorescence completed
			Anthesis
60	10.51	11.4	Beginning of anthesis
65		11.5	Anthesis half-way
69		11.6	Anthesis complete
			Milk development
70			—
71	10.54	12.1	Kernel watery ripe
73		13.0	Early milk
75	11.1		Medium milk
77			Late milk
			Dough development
80			—
83		14.0	Early dough
85	11.2		Soft dough
87		15.0	Hard dough
			Ripening
90			—
91	11.3		Kernel hard (difficult to divide by thumbnail)
92	11.4	16.0	Kernel hard (can no longer be dented by thumbnail)
93			Kernel loosening in daytime
94			Overripe, straw dead and collapsing
95			Seed dormant
96			Viable seed giving 50% germination
97			Seed not dormant
98			Secondary dormancy induced
99			Secondary dormancy lost

**The Haun scale stages used in this example from boot through ripening are based on a seven-leaf plant.

[1]From University of Idaho MS 118, *Growth Staging of Wheat, Barley and Wild Oat.*

Rotation Factors and Field Selection

Irrigated spring wheat can be grown in rotation with other irrigated crops with few restrictions. No significant disease problems are common between spring wheat and potatoes, sugarbeets, alfalfa or field beans. Spring wheat in the rotation breaks disease and weed cycles of those crops. Avoid using soil residual herbicides in rotation crops that may carry over to the spring wheat.

Direct rotation of irrigated spring wheat with other cereal crops is not recommended when alternatives are readily available. Volunteer cereals, which especially occur where spring wheat follows either winter wheat or winter barley, harbor disease and insect pests. Harvesting techniques that minimize grain loss and proper cultivation during seedbed preparation will help control winter cereal volunteer problems. Avoid fields where shatter of winter grains has been excessive.

Variety Selection

Proper variety selection is the most cost-effective means of addressing major disease problems. The proper variety also maximizes the return on investment of other production inputs. Public spring wheat varieties developed in Idaho and Washington have been extensively tested for production under irrigation in southern Idaho. Proprietary varieties have been tested less extensively, but more are developed each year and marketed in Idaho. Attributes and disease reactions of the major soft white and hard red spring varieties are given in Tables 2 and 3. For a more detailed discussion on public and private spring wheat varieties adapted for production in Idaho, consult University of Idaho EXP 682, *Spring Wheat Varieties for Idaho.*

Table 2. Attributes of soft white and hard red spring wheat varieties adapted for production under irrigated conditions in southern Idaho.

Variety	Attributes
Soft White Spring Wheats	
Bliss	A white-chaffed, awned, semidwarf spring wheat released by USDA-ARS and the Idaho and Oregon Agricultural Experiment Stations in 1983. Bliss is a tall semidwarf with stiff straw and excellent resistance to lodging. Resistant to stripe rust, moderately resistant to black chaff and resistant to black point. Matures 7 days later than Dirkwin and Owens and should not be planted in areas with short growing seasons. Yields significantly less than Treasure and slightly less than the other varieties under irrigation. Its black chaff, black point and lodging resistance make it the variety of choice in areas where these problems persist.
Dirkwin	A white-chaffed, awnless, semidwarf variety released by the USDA-ARS and the Idaho and Oregon Agricultural Experiment Stations in 1978. Intermediate maturity with straw strength similar to Twin and Owens. Resistant to the prevalent races of stripe rust, moderately resistant to powdery mildew, susceptible to black chaff and intermediate among varieties for percent of kernels infected by black point. Resistant to all races of leaf rust found in the Pacific Northwest, except race UN6B that is prevalent in some years. Slightly more susceptible to ergot than other spring wheat varieties. At Aberdeen and Twin Falls, Dirkwin's average yield is similar to Owens and Fieldwin and less than Treasure. Grain test weight is significantly lower than all other varieties except Twin.
Fieldwin Fielder	White-chaffed, awned, semidwarf soft white varieties with moderately stiff straw. Both are susceptible to stripe rust, and chemical rust control is necessary in years when rust is a problem. At Aberdeen, Fieldwin has been similar to Dirkwin and Owens in maturity. Its height averaged 35 inches, and it has shown moderately good resistance to lodging. Fieldwin's yield has been similar to Owens and Dirkwin but lower than Treasure in both the irrigated and dryland trials. Fielder has yielded slightly less than Fieldwin. Fieldwin has had the highest test weight among the soft white wheats tested. Fielder was released by USDA-ARS and the Idaho, Oregon and Washington Agricultural Experiment Stations in 1974, and Fieldwin by USDA-ARS and the Idaho, Oregon and Colorado Agricultural Experiment Stations in 1977.
Owens	A white-chaffed, awned, semidwarf variety released by the USDA-ARS and the Idaho Agricultural Experiment Station in 1981. Averages 34 inches in height under irrigation at Aberdeen. Similar to Twin in straw strength, slightly better than Dirkwin and Treasure and weaker than Fieldwin and Bliss. Early maturity. Resistant to stripe and leaf rust, susceptible to powdery mildew, moderately susceptible to black chaff and often has a higher than average percentage of kernels infected with black point. Irrigated yield is similar to Fieldwin and Dirkwin, slightly better than Twin and Bliss and lower than Treasure. Owens ranks second to Fieldwin among varieties for test weight performance.
Penawawa	A white-chaffed, awned variety released by the Washington and Oregon Agricultural Experiment Stations in 1985. Similar in height to Owens and Treasure. Penawawa has slightly stiffer straw than Owens and Treasure and slightly better lodging resistance. Matures 2 days later than Owens. Resistant to moderately resistant to stripe rust, resistant to leaf rust, moderately susceptible to black chaff and moderately susceptible to kernel black point. Penawawa has ranked among the top-yielding soft whites under irrigation in southern Idaho.
Treasure	A white-chaffed, awned, semidwarf variety released by USDA-ARS and the Idaho and Oregon Agricultural Experiment Stations in 1986. Yields have averaged 106 percent of yields of the second ranked variety, Fieldwin, under irrigation at Aberdeen and Twin Falls. Possesses a lower test weight than Fieldwin and Owens, but more uniform kernel size than Owens. Matures 1 to 3 days later than Owens and Dirkwin. Averages 1 inch shorter plant height than Owens and is slightly more resist to lodging. Resistant to prevalent races of stripe rust and moderately susceptible to leaf infection by black chaff. Kernels average 34 percent black point (caused primarily by *Alternaria*), similar to percentages for Twin and Owens, but higher than levels observed on other commercial varieties.
Twin	A white-chaffed, awnless, semidwarf variety released by the USDA-ARS and the Idaho, Oregon and Washington Experiment Stations in 1971. Intermediate in maturity. Not as resistant to lodging as Fieldwin and Bliss, but slightly better than Owens and Treasure. Resistant to stripe rust, susceptible to leaf rust, susceptible to powdery mildew, moderately susceptible to black chaff and has one of the highest percentages of kernel black point among spring wheat varieties. Twin yields equal those of Bliss, 2 bushels per acre less than Owens, Fieldwin and Dirkwin and more than 6 bushels less than Treasure under irrigation. Twin test weight is usually 3 pounds per bushel lighter than Fieldwin and Owens.
Wakanz	A white-chaffed, awned, semidwarf variety released by the Washington Agricultural Experiment Station and USDA-ARS in 1987. Straw strength and maturity similar to Bliss. Moderately resistant to stripe rust, resistant to leaf rust and resistant to the Hessian fly. Yields are similar to Twin and Bliss and slightly lower than Penewawa, Owens and Dirkwin. Grain test weight has averaged 1.5 to 2 pounds per bushel lighter than Penewawa and Owens, respectively.

Soft White Spring Wheat

All contemporary soft white wheat varieties are semi-dwarf types 32 to 36 inches in height. Two new varieties, Bliss and Penawawa, and the older variety, Fieldwin, have slightly better resistance to lodging than the others. Maturity dates of varieties vary, so match variety maturity to local growing season lengths.

Resistance to stripe rust is an essential characteristic of any new variety, and all current varieties except Fielder and Fieldwin possess stripe rust resistance. Growers who plant Fielder and Fieldwin must consider the cost of fungicide application for control if rust becomes a problem. Agronomic data for soft white spring wheats grown under irrigation at Aberdeen and Twin Falls are given in Tables 4 and 5.

Hard Red Spring Wheat

Hard red spring wheats have been developed for high yield under irrigation. Adequately fertilized with nitrogen, newer irrigated hard red spring wheats produce a grain protein content above 14 percent, with satisfactory milling and baking properties. Hard red spring wheats do not normally yield as well as the best soft white varieties grown under equivalent conditions. Hard red spring wheat varieties have larger differences in plant height, maturity date, lodging resistance, test weight and resistance to shattering than soft white spring wheat varieties. Growers should carefully select varieties to fit their specific needs. Prospective growers also should consider the expected premium for high protein spring wheat as well as the expected yield and protein content before selecting a hard red spring wheat variety. Data on the hard red spring wheats are given in Tables 6 and 7.

Spring Durum Wheat

Limited acreage of spring durum wheat is grown in southern Idaho. Most spring durum wheat is grown under contract, with the variety or varieties determined by the contractor. Growing spring durum wheat without an assured market is not recommended. Table 8 contains data obtained on durum varieties at Aberdeen from 1985 to 1987.

Table 2 (cont'd).

Variety	Attributes
Hard Red Spring Wheats	
Bannock	A white-chaffed, awned, early-maturing variety released by USDA-ARS and the Idaho Agricultural Experiment Station in 1972. It is a moderately stiff-strawed, medium-height variety with good resistance to lodging and shattering. Moderately susceptible to stripe and leaf rust when grown under irrigation. Bannock has yielded well in the dryland areas of southern Idaho but is not recommended for production under irrigated conditions.
Borah	A white-chaffed, awned, semidwarf variety released by the USDA-ARS and the Idaho and Oregon Experiment Stations in 1974. Averages 31 inches in height with moderate straw strength. Slightly more susceptible to lodging than other varieties. Intermediate to early in maturity. Resistant to stripe rust, moderately resistant to leaf rust, very susceptible to black chaff and moderately resistant to black point. Plant seed free of black chaff bacteria. Has performed better on dryland than under irrigated conditions compared to other varieties.
Butte	Released by the North Dakota Agricultural Experiment Station in 1979. Plant heights have varied from 34 to 41 inches under irrigated conditions with very weak straw. Has yielded less than Pondera and Copper under irrigation. Butte is among the top varieties for grain protein content, but the baking qualities of Butte are not comparable to Copper and Pondera. Butte has some tolerance to Wheat Streak Mosaic.
Copper	A brown-chaffed, semidwarf variety released by the USDA-ARS and the Idaho and Oregon Agricultural Experiment Stations in 1986. Average height is 32 inches with moderately stiff straw. Maturity is 2 to 3 days later than Pondera. Copper is resistant to stripe rust and moderately resistant to leaf rust, black chaff and kernel black point. Top yielder in irrigated trials from 1981 to 1987. Copper ranks second to Pondera in test weight. Properly fertilized, Copper will produce high yields of grain with a protein content of 14 percent or above. Slightly more susceptible to lodging than Pondera and several of the proprietary varieties.
Fremont	Released by the Utah Agricultural Experiment Station in 1970. A high-quality, moderately stiff-strawed variety that has yielded slightly less than Pondera and Copper in the irrigated nurseries. Moderately resistant to the prevalent races of stripe rust found in southern Idaho.
McKay	A white-chaffed, awned, semidwarf variety released by the USDA-ARS and the Idaho, Oregon and Colorado Experiment Stations in 1981. Average plant height is 35 inches with moderately stiff straw. Slightly better lodging resistance than Borah. Moderately resistant to powdery mildew and resistant to the prevalent races of leaf and stripe rust. McKay and Copper have produced similar yields under irrigation. Grain protein content rarely exceeds 13 percent even under ideal conditions.
Pondera	A white-chaffed, awned, semidwarf variety released by the USDA-ARS and the Montana Agricultural Experiment Station in 1980. Averages 34 inches in height with moderately stiff straw. Better resistance to lodging than Borah and has a good reputation for not lodging under commercial conditions. Resistant to existing races of stripe rust and moderately resistant to existing races of leaf rust. Grown under irrigation at Aberdeen and Twin Falls, Pondera yielded 1.7 bushels per acre less than McKay 5 bushels less than Copper, but ranks highest among the three varieties in grain protein content. Excellent milling and baking qualities, and excellent grain test weight among varieties evaluated.
Spillman	Released by USDA-ARS and the Washington Agricultural Experiment Station in 1987. Resistant to stripe rust. Reactions to black chaff and black point are not known. Three years of data in southern Idaho indicate it is slightly lower in yield and lower in test weight than Pondera and Copper when grown under irrigation.
WestBred 960R	A proprietary white-chaffed, awned, semidwarf variety released by Western Plant Breeders in 1981. Averages 35 inches in height under irrigation with good straw strength. Heading dates are 3 to 4 days earlier than Copper and Pondera. Irrigated yields are comparable to Pondera, with slightly lighter test weight and slightly better grain protein levels. Resistant to stripe rust. Reactions to black chaff and black point are not known. Very susceptible to shattering if allowed to overmature. Harvesting at first maturity reduces shatter losses.

Cultural Practices

Seedbed Preparation

Seedbed conditions that promote rapid germination, uniform emergence and early stand establishment are essential for spring wheat production. Regardless of tillage system used, spring wheat requires a moderately fine but firm seedbed to maximize contact of the seed with soil moisture for rapid, uniform germination. The seedbed should be free of weeds and volunteer crop growth. Overworking a seedbed depletes surface soil moisture and promotes soil crusting. Loose or overworked seedbeds can be firmed with a roller before seeding.

A moderate amount of crop residue to reduce surface erosion is tolerable. Excessive residues will interfere with proper seed placement and will also reduce soil temperatures and delay spring wheat emergence. Heavy residues will require specialized drills to place seed into moist soil without clogging or placing residue in the seed row. Pre-irrigation of the seedbed may be required when winter precipitation is limited. Preplant fertilizer and herbicide applications should be made just before final seedbed tillage operations.

Seeding Dates

Irrigated spring wheat in southern Idaho should be planted as early as conditions for seedbed preparation allow. Optimal seeding dates will vary for location and year, but approximate dates for major spring wheat growing areas are:

Treasure Valley — late February to mid-March
Magic Valley — mid-March to early April
Upper Snake River Plain — late March to late April

Early seeding of spring wheat often results in highest yields. Early-seeded grain generally avoids injury from drought, high temperatures, diseases and insect pests that prevail as the season advances. Early seeding dates that take advantage of cooler, wetter weather also reduce season-long demand for irrigation.

Table 3. Disease reactions of soft white and hard red spring wheat varieties grown under irrigation in southern Idaho.

	Rust					
Variety	**Stripe**	**Leaf**	**Stem**	**Powdery mildew**	**Black chaff**	**Black point**
Soft White						
Bliss	R	MS	S	-	MR	R
Dirkwin	R	MS	S	MR	S	MS
Fielder	S	MS	S	MR	MS	MS
Fieldwin	S	MS	S	MR	MS	MS
Owens	R	R	S	S	MS	S
Penawawa	MR	R	R	S	MS	MS
Treasure	R	MR	MS	S	MS	MS
Twin	R	S	S	S	MS	S
Wakanz	MR	R	R	MS	-	-
Hard Red						
Bannock	MS	MS	S	-	MR	MS
Borah	R	MR	R	-	VS	MR
Bronze Chief	MS	MS	MS	MR	-	-
Butte	MR	MS	R	-	-	-
Copper	R	MR	MR	MS	MR	MR
Fremont	MR	S	S	-	-	-
Kodiak	MS	MS	MS	MR	-	-
McKay	R	R	MR	MR	MR	MS
Pondera	R	MR	MR	MR	MR	MS
Probrand 751	R	MR	R	R	-	-
Spillman	R	R	R	R	-	-
WestBred 906R	R	R	-	R	-	-

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible, - = unknown.

Table 4. Mean yield and test weight comparison of six soft white spring wheats grown under irrigation at Aberdeen and Twin Falls from 1982 to 1986. Heading date, plant height and straw strength values observed at Aberdeen only.

	Yield[1]		Test weight[1]				
Variety	**Avg.**	**% Owens**	**Avg.**	**% Owens**	**Heading date**	**Plant height**	**Straw strength[2]**
	(bu/acre)	(%)	(lb/bu)	(%)		(inches)	
Bliss	78.7	97	58.0	98	7/3	36	1.7
Dirkwin	81.1	100	55.5	93	6/30	34	2.5
Fieldwin	81.3	100	59.7	101	6/30	35	2.1
Owens	81.1	100	59.4	100	6/30	34	2.3
Treasure	86.4	106	58.4	98	7/1	33	2.8
Twin	78.9	97	56.4	95	7/1	33	2.3

[1]Yield and test weight averaged across 10 location years of testing.
[2]1 = strong, 5 = weak.

Table 5. Mean yield and test weight comparison of five soft white spring wheats grown under irrigation at Aberdeen and Twin Falls from 1984 to 1987. Heading date, plant height and straw strength values observed at Aberdeen only.

Variety	Yield[1]		Test weight[1]		Heading date	Plant height	Straw strength[2]
	Avg.	% Owens	Avg.	% Owens			
	(bu/acre)	(%)	(lb/bu)	(%)		(inches)	
Owens	83.7	100	60.3	100	6/27	32	3.3
Penawawa	88.1	105	59.5	99	6/30	31	3.0
Treasure	87.4	104	58.9	98	7/2	34	2.7
Wakanz	82.6	99	58.2	97	7/2	33	2.7
Waverly	84.1	101	59.2	98	6/30	33	3.0
LSD (0.05)	4.3						

[1]Yield and test weight averaged across eight location years of testing.
[2]1 = strong, 5 = weak.

Table 6. Mean yield and test weight comparison of five hard red spring wheats grown under irrigation at Aberdeen and Twin Falls from 1981 to 1987. Grain protein, heading date, plant height and straw strength values observed at Aberdeen only from 1983 to 1986.

Variety	Yield[1]		Test weight[1]		Grain protein[2]	Heading date	Plant height	Straw strength[3]
	Avg.	% Borah	Avg.	% Borah				
	(bu/acre)	(%)	(lb/bu)	(%)	(%)		(inches)	
Bannock	64.6	86	59.3	100	13.8	6/24	37	2.8
Borah	75.2	100	59.3	100	13.4	6/25	31	3.0
Copper	83.5	111	60.2	102	12.9	6/26	32	3.0
McKay	80.2	107	59.3	100	12.4	6/28	35	2.0
Pondera	78.5	102	61.0	103	13.9	6/26	34	2.0

[1]Yield and test weight averaged across 14 location years of testing.
[2]As is moisture basis.
[3]1 = strong, 5 = weak.

Table 7. Agronomic comparison of six proprietary hard red spring wheats to Copper and Pondera under irrigation at Aberdeen in 1986 and 1987.

Variety	Yield	Test weight	Grain protein[1]	Heading date	Plant height	Straw strength[2]
	(bu/acre)	(lb/bu)	(%)		(inches)	
Bronze Chief	57.1	53.9	15.1	6/26	32	2.0
Copper	99.1	59.7	13.4	6/29	35	3.0
Germain's 444	75.8	58.6	13.3	6/24	32	2.0
Kodiak	63.1	50.9	13.6	6/26	24	1.5
Norseman	78.1	57.4	13.7	7/1	32	3.0
Pondera	94.6	61.2	13.4	7/1	38	3.0
Probrand 751	104.1	59.1	12.4	6/26	34	1.5
WestBred 906R	90.7	59.0	13.8	6/26	35	2.0

[1]As is moisture basis.
[2]1 = strong, 5 = weak.

Table 8. Agronomic summary of seven durum spring wheat varieties grown under irrigation at Aberdeen from 1985 to 1987.

Variety	Yield	Test weight	Grain protein[1]	Heading date	Plant height	Straw strength[2]
	(bu/acre)	(lb/bu)	(%)		(inches)	
Modoc	75.6	59.1	13.9	6/25	32	3.0
Irridur	63.4	59.4	14.5	7/4	31	2.8
WAID	52.0	55.3	14.5	7/2	33	3.0
Loyd	56.1	55.9	14.8	7/3	31	1.8
Durox	67.5	60.8	15.3	6/29	37	2.3
WPB881	51.0	55.1	15.5	6/27	31	2.0
Laker	93.4	60.4	12.9	7/2	36	3.5
LSD (0.05)	9.7					

[1]As is moisture basis.
[2]1 = strong, 5 = weak.

Spring wheat requires a minimum soil temperature of 40ºF for germination, but optimum germination and emergence occurs between 55º and 75ºF. Extremely early seeding dates when soil temperatures are too cold can delay emergence and reduce seedling vigor. Irrigated soft white spring wheat yields were highest when the grain was planted from mid to late April at Aberdeen in 1986 (Fig. 1), but yields were reduced with seeding dates later than May 1. Yield losses associated with delayed seeding dates were reduced with increased seeding rates.

Seeding Rate and Seeding Depth

Irrigated spring wheat should be planted at rates of 100 to 125 pounds per acre on a pure live seed (PLS) basis, depending on variety selection and seed size. Actual seeding rates on a PLS basis are calculated by dividing the desired seeding rate by the percentage of pure viable seed in a seedlot determined from standard germination and purity tests:

$$\text{PLS seeding rate (lb/acre)} = \frac{\text{Desired seeding rate (lb/acre)}}{\text{Germination (\%)} \times \text{seed purity (\%)}}$$

Higher seeding rates are recommended for newer semidwarf varieties that produce fewer tillers and are less prone to lodging under irrigated conditions. Average yields of WestBred 906R and Pondera for a 3-year period at Aberdeen were higher with seeding rates of 100 and 125 pounds per acre than with a rate of 75 pounds per acre (Table 9). Higher seeding rates are also recommended with delayed seeding dates. Use certified seed to assure seedlot viability and purity.

Best germination and emergence of irrigated spring wheat occur at seeding depths of 1 to 1½ inches with adequate soil moisture conditions. Deeper seeding of semidwarf varieties often reduces stands and should be avoided. Double disk openers provide the most satisfactory method of seeding spring wheat into moisture at a uniform depth under conventional conditions. Hoe-type openers are less exact in seed placement but can be used with less seedbed preparation than is needed for double disk-type openers. Using press wheels or roller-packers after seeding improves seed contact with soil moisture. Applications of starter fertilizers in the seed row should not exceed 30 pounds of nitrogen and sulfur (N+S) combined per acre.

Rowspacing

Commercial drills with a 6- to 8-inch row spacing provide the best distribution of spring wheat seed for irrigated environments in southern Idaho. Compared to wider row spacings (12 to 14 inches) used under dryland conditions, narrower row spacings permit quicker row closure by the crop and reduce weed competition.

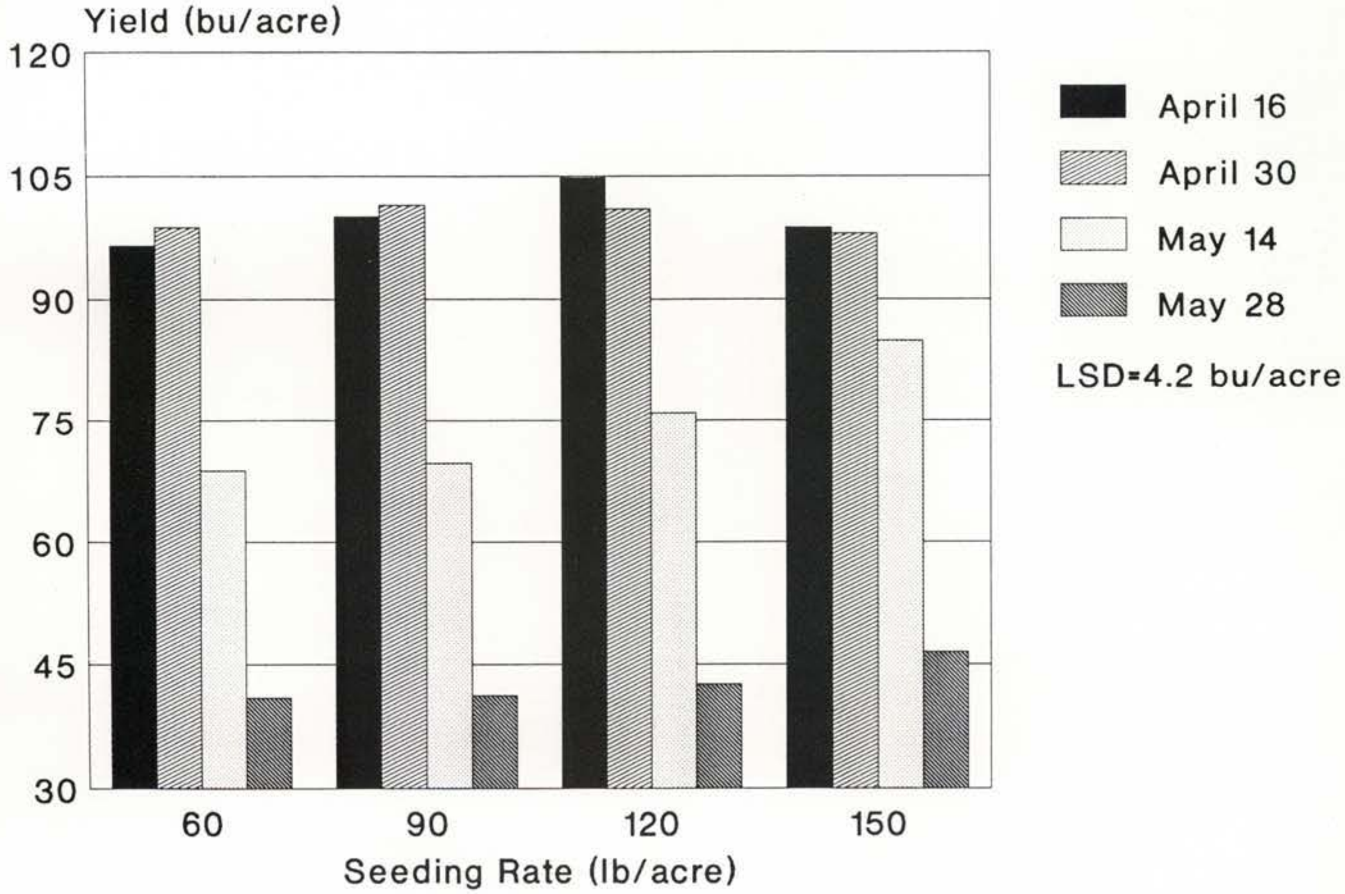

Fig. 1. Yield of Owens soft white spring wheat in response to four planting dates and four seeding rates in 1986 at Aberdeen. Much heavier weed infestations observed with May 28 planting date.

Very narrow row spacings (4 inches or less) have improved spring wheat yields in other wheat-producing regions but offer no appreciable yield advantage under Idaho conditions. Experiments conducted at Aberdeen from 1985 to 1987 compared yields of WestBred 906R and Pondera spring wheat established in row spacings of 4, 8 and 12 inches using seeding rates of 75 to 125 pounds per acre. The 4- and 8-inch row spacings produced the highest yields for both varieties seeded at 100 and 125 pounds per acre (Table 9). No difference in yield between the 4- and 8-inch row spacings were observed for either variety. The cost effectiveness of modifying a commercial drill from 6 or 7 inches to 4-inch configuration would be questionable. Other benefits from adopting very narrow row spacings for irrigated spring wheat production need to be researched further.

Irrigation Management

Irrigation management is one of the most important factors affecting spring wheat yield and quality in southern Idaho. Spring wheat yield potential is determined by the number of heads per unit area, the number of kernels per head and the average grain weight. These yield components are influenced by water availability at different growth stages. Moisture stress at any growth stage before grain soft dough will reduce spring wheat yields, but moisture availability during tillering and from boot to flowering stages has the greatest impact on yield components. Drought conditions during tillering and from boot to flowering stages will cause the greatest yield reductions.

Irrigation scheduling determines the amount of water to apply and matches water applications to meet crop requirements in a timely and efficient manner. Efficient scheduling requires a knowledge of crop water use rates and plant-available soil moisture based on soil water-holding capacities.

Evapotranspiration and Crop Water Use

Evapotranspiration (ET) is the combined loss of water from transpiring plants and surface evaporation during crop growth. Evapotranspiration rates can be used to estimate the demand for supplemental irrigation during crop production. Seasonal ET for irrigated spring wheat in southern Idaho ranges from 15 to 19 inches, depending upon location. Rainfall during the growing season may reduce crop irrigation requirements from 10 to 25 percent.

Daily ET rates reflect daily water use by spring wheat based on crop growth stage and local weather conditions. For example, daily ET rates at Kimberly for seedling spring wheat in April are about 0.04 to 0.08 inch per day (Fig. 2). As plants begin to tiller in May, daily ET rapidly increases. Peak ET rates of greater than 0.30 inch of water per day occur for a period of about 30 days from mid-June to mid-July. Beyond the soft dough, ET rates rapidly fall as the crop matures.

Available Water-holding Capacity of Soil

The amount of water a soil will store for crop use is called the available water-holding capacity (WHC) and is usually expressed as inches of water per foot of soil (inches/foot). Available water-holding capacities differ among soil texture types that occur in southern Idaho. Loam soils usually have WHC values above 2 inches/foot. Sandy soils usually hold less than 1 inch/foot of available water. Sandy loams generally fall somewhere in between. Available water-holding capacities for most agricultural soil series found in southern Idaho are listed in Table 10. Consult University of Idaho CIS 236, *Available Water-holding Capacities of Soils in Southern Idaho*, for detailed information about the WHC of Idaho soils where irrigated spring wheat is grown.

The WHC of a soil profile will vary with depth, since soil texture at different depths can vary considerably. The total WHC of a soil for spring wheat production can be calculated by determining the thickness of the different soil texture layers in the root zone and the WHC of each layer. The total WHC for a soil profile that is sandy in the top foot, but sandy loam in the second and third foot is estimated in Table 11. Total WHC of a soil profile represents the total available soil moisture (ASM) in inches for crop growth between irrigations.

Determining Available Soil Moisture

Available soil moisture can be determined by direct measurement of soil water content or estimated from ET values supplied by local weather data. Direct measurements of ASM include judging soil moisture by feel

Table 9. Yield of WestBred 906R and Pondera hard red spring wheat using 4- to 12-inch row spacings and 75 to 125 pound per acre seeding rates averaged for 1985, 1986 and 1987 growing seasons at Aberdeen.

	Row spacing					
	4-inch		8-inch		12-inch	
Seeding rate	906R	Pondera	906R	Pondera	906R	Pondera
(lb/acre)	(bushels per acre)					
75	96.6	93.4	102.2	100.0	97.8	96.3
100	99.8	105.1	106.7	102.3	99.1	96.8
125	107.0	109.0	107.5	103.1	94.3	98.5

LSD (p = 0.05); Row spacing = 4.8, Seeding rate = 4.2.

and appearance, weighing soil samples before and after drying and using neutron probes or tensiometers.

One of the most convenient methods of estimating soil moisture depletion is called the "water budget" or "checkbook" method (see PNW 288, *Irrigation Scheduling*, and University of Idaho MS 39, *Soil Moisture Scheduling Card*). Once the soil has drained to field capacity 1 to 2 days after full irrigation, further losses of soil moisture occur primarily from ET. If the WHC of the full soil profile and the amount of soil moisture lost to ET each day are known, then the amount of ASM can be estimated by subtracting the sum of the daily ET values. Many local newspapers report estimated ET values for major crops on a daily basis. Remember, water budgets only estimate soil moisture depletion. Periodic measurement of actual ASM levels make estimates more accurate.

Irrigation Scheduling

Studies conducted at Aberdeen with sprinkler irrigation indicate soil moisture levels in the root zone should be maintained above 50 percent ASM throughout the growing season for maximum spring wheat yields (Table 12). During tillering and flowering, soil moisture levels should be maintained above 60 percent ASM because of the greater sensitivity to moisture stress at these growth stages. Overirrigation should be avoided during tillering when only light irrigations are normally required. Excessive irrigation leaches available nitrogen below the root zone, often reducing yield and quality.

To maintain soil moisture above 50 percent ASM, a soil with a total WHC of 4.0 inches in the top 3 feet of the soil profile would need to be irrigated before available soil moisture dropped below 2.0 inches. Table 13 shows how the water budget method can be used to schedule irrigations.

Recommendations for Different Irrigation Systems

Center Pivot Systems — Center pivot irrigation systems will usually not apply enough water to equal peak daily ET values. In July, a center pivot will apply approximately 0.26 inch per day, but ET rates may exceed 0.30 inch per day (Fig. 2). Under these conditions, peak daily crop water requirements will be partially furnished by soil moisture reserves developed before peak use.

Center pivot systems should be started early in the growing season and kept on until the soil root zone is full, or until water has penetrated 2.5 to 3 feet into the soil. Root zone soil moisture levels should be 100 percent ASM by mid-June. Enough water should be ap-

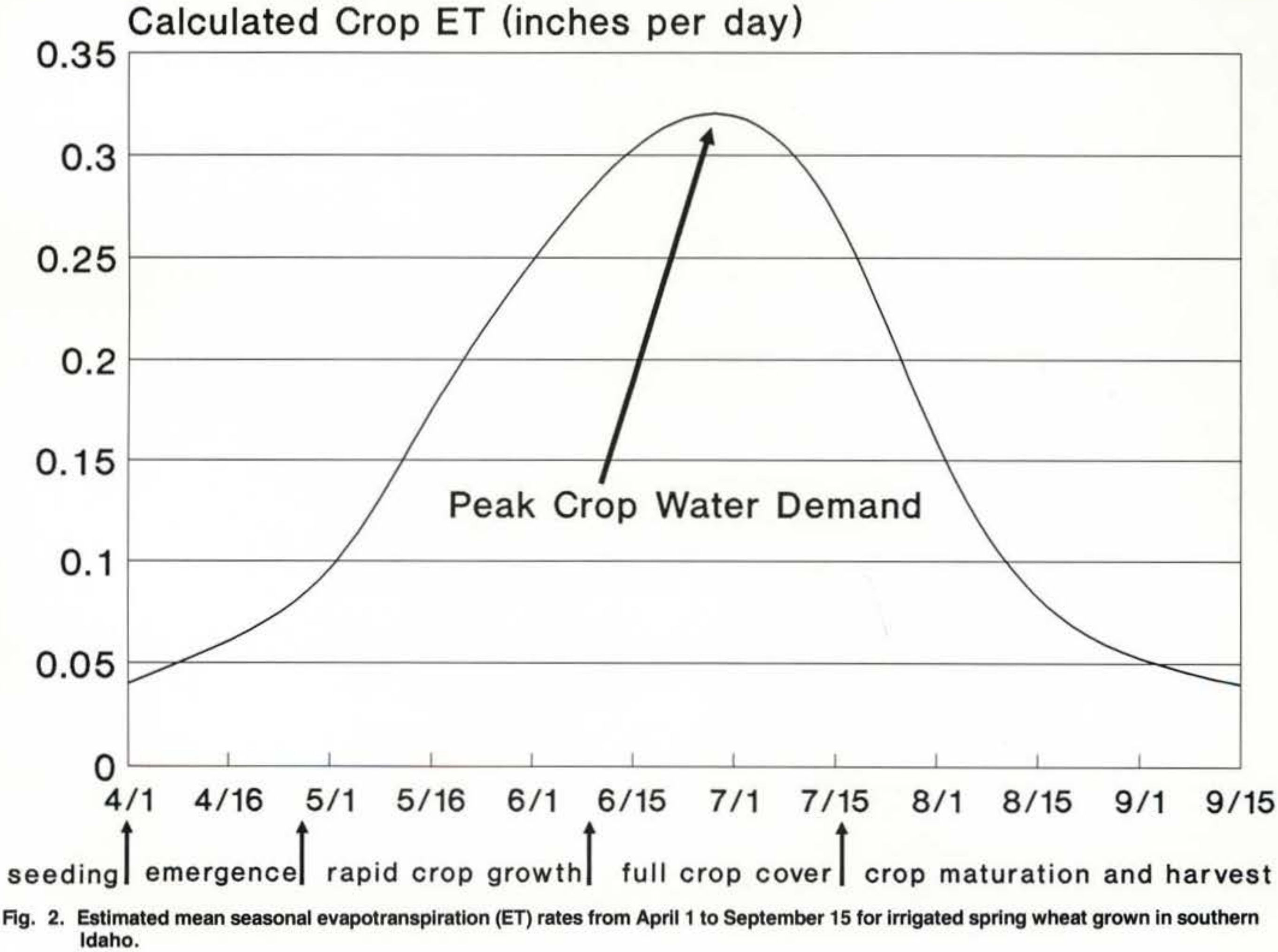

Fig. 2. Estimated mean seasonal evapotranspiration (ET) rates from April 1 to September 15 for irrigated spring wheat grown in southern Idaho.

plied to keep the root zone full or at least maintain soil moisture content above 50 percent ASM. During peak ET periods, center pivot systems should be operated continuously with one rotation every 36 hours. In areas where runoff occurs, some form of basin tillage should be used to minimize erosion. As ET levels decline, pivot application rates will match or exceed ET levels.

Surface Systems — A normal spring wheat crop should have rooted to a 1 foot depth when initial surface irrigation is applied. Infiltration rates are usually high during the initial application of water with gravity systems, and overirrigation often occurs. Except on light sandy soils, the first irrigation should be delayed until soil moisture levels decline to 40 percent ASM at the 4- to 6-inch depth. This depletion level usually corresponds to late tiller development of the spring wheat. Fall pre-irrigation may be required to assure adequate soil moisture at planting in dry winter areas. Spring pre-irrigation in dry winter areas will delay seeding dates. Soil moisture levels should be maintained at or above 60 percent ASM from the boot to flowering stages of growth. Soil moisture levels can be depleted to 50 percent ASM between later irrigations.

Side-Roll and Hand-Moved Systems — Side-roll and hand-moved irrigation systems should saturate the soil 6 to 8 inches deep during the first irrigation. Schedule initial sets early to prevent soil moisture from drying below 50 percent ASM (60 percent ASM during tillering and from boot to flowering) at the 4- to 6-inch depth on the final set of the first irrigation. The second irrigation pass should apply enough water to penetrate the soil profile down to sub-surface moisture. This may require 12- to 24-hour sets, depending upon soil type, texture and depth. To reduce the number of irrigations on medium textured soils and save labor, subsequent irrigations can employ 24-hour sets and should be timed to avoid soil moisture depletion below 60 percent ASM levels on the final set. Since it takes longer to cover a field with 24-hour sets, the conversion from 12- to 24-hour sets should begin early enough to avoid over-depletion of ASM on the final set.

Scheduling the Last Irrigation

Unneeded irrigations consume energy, waste water needed by other crops, increase lodging risks and inflate production costs. Irrigators often apply more late-season irrigations than necessary for optimum spring wheat yields. Spring wheat requires about 2.5 inches of available soil moisture from the soft-dough stage of development to crop maturity. (At the soft-dough stage, fully formed kernels exude contents with a meal or dough texture when pressed between thumb and index finger.) On soil profiles possessing a total WHC equal to or greater than 2.5 inches, the last irrigation can be applied at the soft dough stage. Soil profiles possess-

Table 11. Example calculation of total available soil moisture (ASM) for a soil profile containing different soil types.

Soil type per layer	Soil layer thickness		Available WHC		WHC per soil layer
	(feet)		(inches/foot)		(inches)
Sandy	1.0	×	1.0	=	1.0
Sandy Loam	2.0	×	1.5	=	3.0
Total ASM (inches)					4.0

Table 10. Water-holding capacities (WHC) for agricultural soil series in southern Idaho by soil texture type.

Soil series	Water-holding capacity	Soil series	Water-holding capacity	Soil series	Water-holding capacity
	(inches/foot)		(inches/foot)		(inches/foot)
Sandy types		**Silt types**		**Silt loam types**	
Feltham	0.65	Minidoka-Scism	2.12	Baldock	3.34
Quincy	0.41	**Clay loam types**		Bancroft	2.60
Sqiefel	0.38	Terreton	1.08	Blackfoot	2.25
Loamy sand types		**Silty clay loam types**		Colthorp	2.24
Chedehap	1.65	Annis	2.10	Elijah	2.81
Diston	0.65	Monteview	2.03	Gooding	2.13
Egin Bench	1.67	Unclassified	2.28	Greenleaf	2.18
Feltham	0.70	**Loam types**		Hayeston	2.45
Grassy Butte	0.36	Bock	1.80	Lanark-Bancroft	2.69
Heiseton	1.52	Declo	2.01	Lankbush	2.79
Rupert	0.76	Drax	2.41	Minidoka	1.80
Tindahay	0.62	Garbutt	2.46	Neeley	2.19
Vining	0.45	Heiseton	2.09	Nyssaton	2.49
Zwiefel	0.47	Hunsaker	2.24	Pancheri	2.15
Sandy loam types		Marsing	2.17	Pocatello	1.85
Falk	2.28	Paulville	3.19	Power	2.45
Matheson	1.05	St. Anthony	1.41	Power-Purdam	2.44
Turbyfil	1.67	View	1.94	Portneuf	2.54
Fine sandy loam types		Unclassified	2.41	Purdam	2.87
Cencove	1.44	**Silty clay types**		Rexburg	1.97
Turbyfil	1.49	Abo	2.98	Robana	2.22
Unclassified	1.22	Goose Creek	2.85	Scism	2.35
Sandy clay loam types		**Clay types**		Tetonia	2.09
Terreton	1.12	Terreton	1.94		

ing a total WHC of less than 2.5 inches may require irrigation after soft dough, but total water applied beyond the soft dough stage should not exceed 2.5 inches.

Fertility

Determining Fertilizer Requirement

Proper soil sampling is essential to accurately estimate fertility requirements of irrigated spring wheat. Soil fertility conditions often differ both within and between production fields. Each soil sample submitted to a soil testing laboratory should consist of subsamples collected from at least 20 individual sites within a representative area to a depth of 24 inches. Collect 20 subsamples from the 0- to 12-inch depth and 20 subsamples from the 12- to 24-inch depth. Subsamples should not be taken from gravelly areas, turn rows, wet spots and field borders. Thoroughly mix the 20 subsamples from each depth in a clean plastic bucket. Place approximately 1 pound of soil from each depth into a plastic-lined soil bag and label with grower name, depth, date and field number before submitting to a testing laboratory.

Nitrogen

Nitrogen (N), which is necessary for maximum yield of irrigated spring wheat, accounts for the largest share of fertilizer costs for wheat production. The amount of N required to generate optimum economic return depends on numerous factors, but residual inorganic N levels, previous crop residue levels and the total N requirement are the three factors used to determine spring wheat N fertilizer needs.

Interpreting Nitrogen Soil Test Results — Soil test nitrate (NO_3-N) and ammonium (NH_4-N) values are typically reported in parts per million (ppm). To convert soil test NO_3-N and NH_4-N values to pounds N/acre, add the soil test N values (ppm) for each foot and multiply by 4 as shown in Table 14.

Previous Crop Residue — The N required to decompose previous crop residues must be estimated in formulating N fertilizer needs. Soil microbes decomposing cereal straw and corn stalks remove plant available N from the surrounding soil. About 15 pounds N/acre are needed per ton of straw returned to the soil, up to a maximum of 50 pounds N/acre. Row crop residues (potatoes, sugarbeets, onions) have little effect on N requirements of wheat and do not require additional N for decomposition.

Crop residues and nodulated root systems from beans, peas and alfalfa release significant amounts of N as they decompose. Bean and pea residues readily decompose, and the level of N released can be readily assessed by spring soil samples. Fall-plowed alfalfa stubble will provide an additional 40 to 60 pounds available N/acre for spring wheat crops that will not be detected by spring soil testing.

Table 13. Water budget for a spring wheat crop grown on a soil with a total available water-holding capacity of 4.0 inches in the top 3 feet. Allowable depletion is 50 percent of 4.0 inches = 2.0 inches.

Date	Daily[1] ET	Cumulative ET	Available soil moisture	Action
	(inches per day)	---------- (inches)	----------	
6/17			4.00	Irrigate
6/18	0.25	0.25	3.75	
6/19	0.26	0.51	3.49	
6/20	0.23	0.74	3.26	
6/21	0.26	1.00	3.00	
6/22	0.27	1.27	2.73	
6/23	0.25	1.52	2.48	
6/24	0.22	1.74	2.26	
6/25	0.24	1.98	2.02	Check soil moisture
6/26	0.26		4.00	Irrigate
6/27	0.24	0.24	3.76	
6/28	0.25	0.49	3.51	
6/29	0.23	0.72	3.28	
6/30	0.24	0.96	3.04	
7/1	0.24	1.20	2.80	
7/2	0.26	1.46	2.54	
7/3	0.26	1.72	2.28	
7/4	0.24	1.96	2.04	Check soil moisture
7/5	0.25		4.00	Irrigate

[1]Published in most daily newspapers across southern Idaho every Tuesday and Friday.

Table 12. Influence of irrigation scheduling on grain yield of four spring wheat varieties at Aberdeen.

Irrigation treatment[1]	McKay	Borah	Owens	Bliss	Mean	Water applied	Irrigations required
	Variety						
(% ASM)	---------- (bushels per acre) ----------					(inches)	(number)
1982							
30/45	69.7	65.8	75.8	75.8	71.8	10.7	6
45	84.5	78.2	87.4	83.6	83.4	13.8	8
60	92.6	81.5	88.3	88.8	87.8	14.6	12
LSD (p = 0.05)	10.2	9.9	10.0	9.2	6.7		
1983							
30/45	91.1	89.6	95.7	87.8	91.1	13.4	6
45	99.3	99.8	98.8	92.2	97.5	15.5	8
60	99.5	103.9	108.2	96.4	102.0	16.5	11
LSD (p = 0.05)	8.3	8.8	10.4	5.1	5.7		

ASM = Available soil moisture

[1]ASM was allowed to decrease to 30, 45 or 60 percent before irrigating. Sufficient water was applied to raise soil water content to field capacity. The lower limit for the 30/45 treatment was raised to 45 percent during flowering.

Spring Wheat Nitrogen Requirements — Maximum yields of irrigated spring wheat occur at about 160 pounds of residual plus applied nitrogen per acre (Fig. 3). The data represent N response of spring wheat on silt loam soils typical for irrigated areas of southern Idaho, and was derived from field studies using several varieties of both soft white and hard red spring wheat. Nitrogen derived from mineralization during the growing season is included in the total N levels. Coarse-textured soils (sandy and sandy-loam types) with poor N use efficiencies usually require higher N rates. Light applications of N (less than 20 lb N/acre) on sandy soils during tillering have sometimes proved to be beneficial.

Avoid excessive N fertilizer rates. Straw strength is often reduced by excess N. Total N levels above recommended rates increase the likelihood of lodging with a subsequent reduction in harvestable yield. The lush vegetative growth associated with excessive N rates also can promote foliar diseases such as rust and powdery mildew.

Nitrogen Application Rates — Nitrogen fertilizer rates for irrigated spring wheat are determined using spring soil test N levels and identification of the previous crop (Table 15). For example, a field previously cropped to alfalfa with a soil test indicating 40 pounds N/acre would require the addition of 60 pounds N/acre. Note the recommendations for spring wheat following alfalfa have been adjusted by 60 pounds N/acre for the additional N released from fall-plowed alfalfa stubble.

Managing Nitrogen for High Grain Protein — Premiums are often paid for high protein hard red spring wheat. Nitrogen requirements for maximum yield of hard red and soft white spring wheats do not differ, but N management for production of high protein grain requires additional considerations. Current hard red spring wheat varieties differ in their ability to produce high protein grain (see Variety Selection). High spring wheat yields and high grain protein levels can be achieved using split applications of N fertilizer under irrigated conditions. Applying 25 to 30 pounds of N per acre from heading to flowering is the most effective approach for increasing grain protein by split nitrogen applications.

Basic N management for high protein hard red spring wheat involves these steps:

1. Determine the total amount of fertilizer N required based on residual soil inorganic N and previous crop residues.
2. Apply all but 25 to 30 pounds N/acre preplant.
3. Apply the remaining 25 to 30 pounds N/acre during the period between heading and flowering.

Phosphorus

Spring wheat phosphorus (P) requirements are typically less than P requirements of other crops grown in southern Idaho. Adequate soil P levels are necessary for maximum production. Soil test results indicating less than 11 ppm of P in samples taken at the 0- to 12-inch depth reflect deficient soil phosphorus levels for spring wheat production. Phosphorus fertilizer rates based on soil test P levels are shown in Table 16.

Broadcast incorporating or drill banding low rates of P with the seed are effective methods of application. Drill banding may reduce the fertilizer P required. Drill banding high rates of P, especially ammonium phosphate fertilizers, can cause seedling damage. For more information on fertilizer banding, refer to PNW 283, *Fertilizer Band Location for Cereal Root Access*.

Table 14. Example calculation of residual N.

Sample depth	NO_3-N	NH_4-N	Total NO_3-N and NH_4-N			Total NO_3-N and NH_4-N
(inches)	(ppm)	(ppm)	(ppm)		Multiplier	(lb/acre)
0 to 12	13	2	15	×	4	60
12 to 24	6	2	8	×	4	32
Total	19	4	23	×	4	92

Table 15. Nitrogen fertilizer rates based on spring soil test and previous crop.

Spring[1] soil test (0 to 24 inch)	Apply these N rates when following: Alfalfa	Row crop	Grain[2]
(lb N/acre)	(lb N/acre)		
0	100	160	210
20	80	140	190
40	60	120	170
60	40	100	150
80	20	80	130
100	0	60	110
120	0	40	90
140	0	20	70
160	0	0	50

[1]Based on calculation method from Table 14.
[2]All crop residue returned.

Table 16. Phosphorus fertilizer rates based on soil tests.

Soil test P[1] 0 to 12 inches	P rates of application[2] P_2O_5	P
(ppm)	(lb/acre)	
0 to 3	160	70
4 to 7	120	53
8 to 11	60	26
over 12	0	0

[1]$NaHCO_3$ extraction
[2]Phosphorus is expressed as both the oxide and elemental forms: $P_2O_5 \times 0.44 = P$ or $P \times 2.29 = P_2O_5$

Table 17. Potassium (K) rates based on soil tests.

K soil test[1] 0 to 12 inches	Potassium rates[2] K_2O	K
(ppm)	(lb/acre)	
0 to 21	240	200
22 to 45	160	133
46 to 68	80	66
over 68	0	0

[1]$NaHCO_3$ extraction
[2]Potassium is expressed as both the oxide and elemental form: $K_2O \times 0.84 = K$ or $K \times 1.20 = K_2O$

Potassium

Spring wheat has lower potassium (K) requirements compared to sugarbeets, corn or potatoes, but intense cropping of southern Idaho soils may be decreasing the natural abundance of this essential nutrient to deficient levels. Test soil to indicate the need for supplemental K. Recommended K application rates based on soil test results are given in Table 17. Potassium does not readily move in soil and should be incorporated during final seedbed preparation.

Sulfur

Sulfur (S) fertilizer requirements for irrigated spring wheat production will vary depending on soil texture, previous crop residues, leaching, S content of irrigation water and residual S levels. Sulfur acts much like N in the soil. Nearly all residual S is organic and must be "mineralized" to sulfate (SO_4-S) for plant uptake. Wheat irrigated with Snake River water should not be S deficient. Soils low in S (less than 10 ppm SO_4-S in the plow layer or 8 ppm in the 0- to 12- inch depth) should receive 20 to 40 pounds of S per acre. Elemental S requires microbial conversion to the SO_4-S form for plant uptake. Therefore, elemental S applications may not provide sufficient levels of plant available SO_4-S to quickly alleviate S deficiencies.

Micronutrients (Fe, Mn, Zn, Cu, B)

Irrigated spring wheat has not responded to micronutrient applications in southern Idaho. Spring wheat responses to micronutrient applications are not expected except occasionally on severely scraped soils. Applying micronutrients without proper guidelines poses a greater chance of creating toxicity problems than correcting deficiencies.

Lodging

Lodging delays maturity, increases harvest costs and decreases yields and quality. The incidence of lodging is increased by dense stands, high N fertilization, excess irrigation, crown and root rot diseases and poor straw strength. Selection of varieties with improved straw strength will minimize lodging problems.

The plant growth regulator ethephon (Cerone) is registered for use on irrigated spring wheat to reduce lodging in crops managed for maximum yields. Ethephon requires exact timing of application to be effective. Apply ethephon from the time the flag leaf is just visible to the boot stage of crop development. Do not apply if awns are visible or the head is exposed. Do not exceed labeled rates. Improper ethephon application can result in crop damage. Inspect spring wheat fields to determine exact growth stage and **ALWAYS read the label for rates and conditions before using ethephon for lodging control.**

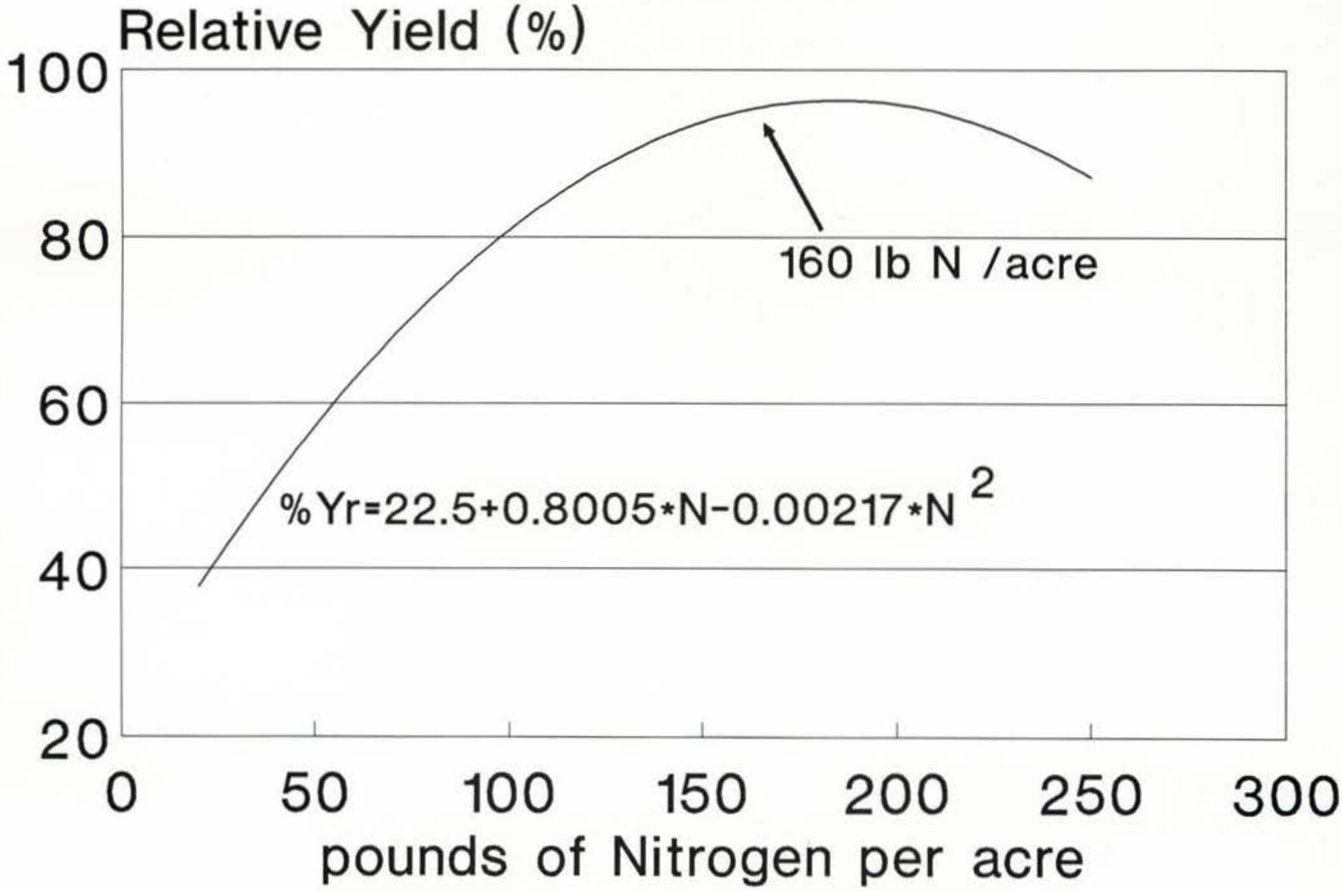

Fig. 3. Relative yield of irrigated spring wheat as a function of total plant available nitrogen (residual + applied).

Weed Control

Weed control in irrigated spring wheat is essential for optimum grain yield and crop quality. Wild oat (*Avena fatua*), common lambsquarters (*Chenopodium album*), pigweeds (*Ameranthus* species), hairy nightshade (*Solanum sarrachoides*), Kochia (*Kochia scoparia*) and various mustards are annual weeds commonly found in irrigated spring wheat. Canada thistle (*Cirsium arvense*) and quackgrass (*Agropyron repens*) are the most common perennial weeds.

Successful weed control depends on the integration of the best cultural and chemical control tactics. Cultural practices include adequate weed control in the rotation crops, field border sanitation, use of clean seed, crop rotation, good seedbed preparation and agronomic practices that promote a healthy, competitive crop. Many herbicides are registered for selective weed control in irrigated spring wheat. Before using any herbicide, **ALWAYS carefully read the label**. Factors affecting the proper choice of a herbicide include spring wheat variety to be planted, crop rotation, soil characteristics and weed species.

Cultural Weed Control

A fundamental aspect of an integrated weed management program is to prevent weeds from spreading to noninfested fields. Plant weed-free seed (see University of Idaho CIS 767, *Weed Seed Contamination of Cereal Grain Seedlots — A Drillbox Survey*), and keep ditch banks, fence rows, roadsides and other noncrop areas free of weeds. Clean tillage and harvest equipment thoroughly between fields to remove weed seeds and other reproductive structures such as roots and rhizomes of perennial weeds.

Good weed control in the crops preceding irrigated spring wheat usually means fewer weed problems in the wheat. Weeds left uncontrolled will produce seed to infest subsequent crops. One wild oat plant per 20 square yards (242 wild oat plants per acre) left uncontrolled will not affect grain yield. Each plant can produce about 225 seeds (55,000 seeds per acre) and if only half of these seeds germinate, 6 wild oat plants per square yard (29,000 per acre) will establish during the next growing season.

If left uncontrolled, these plants will produce more than 6.5 million wild oat seeds per acre (150 per square foot). Similar or greater increases in weed seed numbers can be expected for other weed species. Crop rotation helps prevent this buildup of weeds because differences in tillage, planting time, length of growing season and types of herbicides used for different crops disrupt weed life cycles or destroy weed seed in soil.

Well adapted, disease resistant varieties planted at the proper time, seeding rate and row spacing with adequate soil moisture and fertility, will aggressively compete with many weed species. Spring wheat seedlings that emerge before weeds capture more water, nutrients and light, and grow faster than later emerging weeds.

Chemical Weed Control

Weed Identification — Correct identification of weed species is necessary for proper herbicide selection, proper application rates and correct timing. Weeds are most difficult to identify in the seedling stage when herbicides are usually most effective and should be applied. University of Idaho Extension agents, Extension weed specialists and industry fieldmen can help identify weed seedlings. (Also see *Common Weed Seedlings of the United States and Canada*, a publication available from UI Cooperative Extension Offices.)

Variety-Herbicide Interactions — Spring wheat cultivars are tolerant of, not resistant to, registered wheat herbicides. Tolerance is the degree to which plants fail to respond to an applied herbicide. Tolerance levels vary among spring wheat cultivars for the many herbicides registered for use on wheat. For example, difenzoquat (Avenge) herbicide can be applied only to the hard red spring wheat varieties listed on the label but is not restricted for use with soft white varieties.

Because varieties can differ in their tolerance to herbicides, limit initial use of a herbicide on a new variety or a new herbicide on any variety to a small area BEFORE using it field-wide. NEVER treat susceptible varieties listed on a herbicide label with that herbicide. **ALWAYS read and follow instructions on the label when using a registered herbicide for spring wheat production.**

Herbicide Rotation Restrictions — **ALWAYS read and study crop rotation restrictions on herbicide labels**. Some herbicides persist in the soil and injure subsequent rotation crops. Herbicide persistence is related to soil characteristics such as pH, temperature, moisture and ion exchange capacity. The herbicide application rate and interval between crops also influence herbicide carryover.

General Herbicide Selection — Table 18 is a guide for herbicide control of annual weed infestations in irrigated spring wheat. The ability of wild oat to reproduce quickly and adapt to a wide range of environments has made it the most serious weed problem in irrigated spring wheat. For more information on dealing with wild oat control problems, refer to University of Idaho CIS 540, *Wild Oat Identification and Biology*; CIS 541, *Wild Oat Competition and Crop Loss*, and CIS 584, *Wild Oat Cultural Control*.

Quackgrass cannot be controlled selectively in spring wheat. Apply glyphosate (roundup) for quackgrass control before planting. Table 19 is a guide for herbicide control of Canada Thistle in irrigated spring wheat. Repeated treatments are usually required for long term perennial wed control. **ALWAYS read and follow the label before applying any registered herbicide to control perennial weeds.**

Table 18. Guide to herbicides registered for weed control in irrigated spring wheat in Idaho. This table is only to suggest possibilities. Strictly follow label directions when using herbicides.

Herbicide[1]	Rate	Comments
	(a.i. per acre)	
Wild oat only		
triallate (Fargo)	1 to 1.25 lb	Use 1.0 lb per acre of emulsifiable herbicide or 1.0 to 1.25 lb of granular herbicide. Apply in fall within 3 weeks of normal freezeup or until snow cover or right before or right after seeding. Immediately incorporate spring applications with two harrowings at right angles. When field is trashy or cloddy, weed control may be reduced due to poor incorporation. Do not graze treated areas.
barban (Carbyne)	0.25 to 0.38 lb	Apply when the majority of wild oats are in the 1- to 2-leaf stage of growth. Use a minimum of 5 gal of water carrier per acre at 45 psi. There is a difference in wheat varietal tolerance to barban (study the label). Do not graze until after harvest.
difenzoquat (Avenge)	0.63 to 1.0 lb	Apply when the majority of wild oats are in the 3- to 5-leaf stage of growth. Do not apply when freezing temperatures are forecast or when plants are wet. Use the lower rate for a wild oat population of 1 to 10 per square foot. Use a medium rate for 11 to 25 and the high rate for more than 25 plants per square foot. Difenzoquat will not control other weeds. Do not graze treated fields. There is a difference in wheat varietal tolerance to difenzoquat (study the label). Do not make more than one application per growing season.
imazamethabenz (Assert)	0.47 lb	Apply when majority of the wild oats are in the 1- to 4-leaf stage of growth. Assert also will control certain annual broadleaf weeds such as wild mustard, tansy mustard, flixweed, field pennycress and wild buckwheat. Read the Assert label for tank mix instructions and restrictions. Except for barley, corn, potatoes, sunflowers and wheat, do not plant rotational crops within 15 months of application on spring wheat. Assert is less effective in controlling weeds hardened by cold weather or drought stress, and regrowth may occur.
Wild oat, barnyardgrass, green foxtail, Italian ryegrass		
diclofop methyl (Hoelon)	0.75 to 1.25 lb	Apply when the majority of annual grasses are in the 2- to 3-leaf stage of growth. Apply before the 1-node stage of wheat growth. Larger grasses (3 to 4 leaves) will require the higher rate. Do not tank-mix diclofop methyl with any herbicide except bromoxynil. Do not apply other herbicides within 5 days of a diclofop methyl application. When applied under dry conditions, crop oil concentrate may be used at 0.5 to 1 pint/acre for applications by air and 0.5 pint/acre for ground application. Do not graze treated fields. Do not make more than one application per growing season. Diclofop methyl is a restricted-use herbicide.
Annual broadleaf weeds		
bromoxynil (Buctril 2EF)	0.38 to 0.5 lb	Apply as soon as the weeds have germinated. Effective control is on weeds less than 1 inch in size. Do not graze for 30 days.
bromoxynil + MCPA (Bronate)	0.38 to 0.5 lb	Apply when the wheat is in the 3- to 5-leaf stage of growth. Best control is obtained when the weeds have less than 4 leaves or are less than 2 inches In size. Do not graze for 30 days.
2,4-D or MCPA	0.5 to 1 lb	Apply as soon as the wheat is 4 to 8 inches tall (3 to 5 inches tall for MCPA) but before the 2-node stage of wheat growth. Do not graze or feed forage within 2 weeks after treatment with 2,4-D. Do not permit 2,4-D or MCPA to drift off target.
dicamba (Banvel)	0.125 lb	Apply when wheat is in the 2- to 5-leaf stage of growth. To avoid crop injury, apply to wheat at the proper stage of growth. Will control some weeds not controlled by 2,4-D. Do not apply to wheat underseeded to legumes. Do not permit dicamba to drift off target. Do not graze or harvest for dairy feed prior to crop maturity.
chlorsulfuron (Glean)	0.125 to 0.375 oz	NOTE: Application rate is in ounces of active ingredient (a.i.) per acre. Maximum use rate is 0.375 ounces a.i. per acre on soils having a pH of 6.5 or lower. Maximum use rate is 0.25 ounces a.i. per acre on soils with a pH of 6.6 to 7.5. Do not use on soils above pH 7.5. Apply postemergence after wheat has 2 to 3 leaves and before the boot stage. Apply before weeds are 2 inches tall or 2 inches in diameter. Chlorsulfuron will control a wide range of broadleaf annuals and will inhibit Canada thistle. It will not control nightshades. See label for other pH restrictions. Chlorsulfuron can persist in the soil. Follow label instructions carefully regarding crop rotation. Susceptible crops may not be planted for 3 to 4 years or longer after application. Do not apply to irrigated land where tail water will be used to irrigate other cropland. Read the label for tank mix instructions and restrictions. **ALWAYS tank mix with other broadleaf herbicides that have a different mode of action.**
metsulfuron (Ally)	0.0625 oz	NOTE: Application rate is in ounces of active ingredient per acre. Apply postemergence from 2-leaf stage, but before boot stage. Do not use on soils above pH 8.0. Do not apply to irrigated land where tail water will be used to irrigate other cropland. Metsulfuron can persist in soil for up to 34 months and injure susceptible non-cereal rotation crops. Read the label for tank mix instructions and restrictions. **ALWAYS tank mix with other broadleaf herbicides that have a different mode of action.** Metsulfuron can be mixed with 2,4-D.
DPXM 6316 (Harmony)	0.25 to 0.5 oz	NOTE: Application rate is in ounces of active ingredient per acre. Apply postemergence from 2-leaf stage of wheat, but before the flag emerges. Harmony has little or no soil activity. Only emerged weeds will be controlled. Avoid applications when rainfall is threatening. No rotational crop restrictions 60 days after last application. Read the label for tank mix instructions and restrictions. **ALWAYS tank mix with other broadleaf herbicides that have a different mode of action.**

(cont'd on next page)

Herbigation — Some herbicides are labeled for application through irrigation systems, but additional restrictions often apply so examine the herbicide label carefully. Consult USDA Extension Service Bulletin, *Application of Herbicides Through Irrigation Systems*, and University of Idaho CIS 673, *Application of Agricultural Chemicals in Pressurized Irrigation Systems*, for more detailed information on applying herbicides with irrigation water.

Insect Pests

At least 20 insect species can attack irrigated spring wheat in southern Idaho. Aphids and wireworms are the most commonly encountered insects that damage spring wheat. Basic descriptions and recommended controls of other insect pests are in the most recent *Pacific Northwest Insect Control Handbook* published annually by the University of Idaho, Oregon State University and Washington State University.

Aphids

Aphids cause greater economic loss than all other insect pests of irrigated spring wheat in Idaho. Six aphid species are known to infest spring wheat, but the English grain aphid (*Macrosiphum avenae*), Russian wheat aphid (*Diuraphis noxia*) and greenbugs (*Schizaphis graminum*) are most commonly associated with significant yield loss. The rose grass aphid (*Metopolophium dirhodum*), corn leaf aphid (*Rhopalosiphum maidis*) and bird cherry-oat aphid (*Rhopalosiphum padi*) normally do not require control. Wheat aphids readily intermingle, with several species occurring in mixed infestations.

Rational control decisions for aphid pests depend on accurate identification. For identification help, two

Table 18 (cont'd)

Herbicide	Rate	Comments
bromoxynil (ME4 Brominal) + dicamba (Banvel)	0.25 to 0.38 lb + 0.125 lb	Apply when the wheat is in the 5-leaf stage of growth and weeds are less than 1 inch in size. Use the higher rate on the larger weeds. See labels for grazing restrictions.
clopyralid/2,4-D (Curtail)	0.6 lb	Extremely effective on weed species of the sunflower family, such as Canada thistle and prickly lettuce. Can be tank-mixed with other herbicides to provide a broader spectrum of broadleaf control. Can be tank-mixed with difenzoquat (Avenge) wild oat herbicide. Do not plant potatoes, peas, beans, lentils or other broadleaf crops grown for seed for 18 months after last application. Wheat, barley, oats, other grasses and sugarbeets may be planted after spring wheat. Avoid drift onto susceptible crops or lands to be seeded to susceptible crops.

Table 19. Guide to herbicides registered for Canada thistle control in irrigated spring wheat. This table is only to suggest possibilities. Strictly follow label directions when using herbicides.

Herbicide	Rate	Comments
	(a.i. per acre)	
Canada thistle only		
chlorsulfuron (Glean)	0.25 to 0.375 oz	NOTE: Application rate is in ounces of active ingredient per acre. Apply after the majority of thistles have emerged and while they are in the rosette stage (4 to 6 inches tall) and actively growing. A single application will inhibit the ability of Canada thistle to compete with the crop. Repeat yearly treatments will be required for long-term control. See comments under annual broadleaf weed control in Table 18.
metsulfuron (Ally)	0.0625 oz	NOTE: Application rate is in ounces of active ingredient per acre. Apply after the majority of thistles have emerged and are in the rosette stage (4 to 6 inches tall) and actively growing. This application will suppress Canada thistle growth and vigor. See comments under annual broadleaf weed control in Table 18.
2,4-D amine or MCPA	0.75 lb	Apply to actively growing weeds when the wheat is 4 to 5 inches tall but before elongation of the stems.
2,4-D amine or MCPA	1.5 lb	Apply to actively growing weeds when the wheat is in the dough stage of growth.
2,4-D amine or MCPA	2.0 lb	Apply to actively growing weeds immediately after grain harvest and before weeds go into dormancy.
clopyralid/2,4-D	0.6 lb	Apply when the majority of basal leaves of Canada thistle have emerged, but before the bud stage. For best control, do not disturb treated plants for 20 days. Do not plant potatoes, peas, beans, lentils or other broadleaf crops grown for seed for 18 months after last application. Wheat, barley, oats, other grasses and sugarbeets may be planted after spring wheat. Avoid drift onto susceptible crops or lands to be seeded to susceptible crops.
dicamba (Banvel)	4 to 6 lb	Spot application only. Apply to actively growing weeds in wheat stubble. Dicamba at this rate usually causes injury to the following wheat crop. Do not plant treated areas to a broadleaf crop for 2 or more years.
glyphosate (Roundup)	2 to 3 lb	After harvest application. Allow at least 4 weeks for initiation of active growth and rosette development before applying the product. Apply before a killing frost. Allow 3 days after application before tillage.

University of Idaho publications are available — CIS 816, *Aphids Infesting Idaho Grain and Corn*, and MS 109, *Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest.* University of Idaho extension agents, Extension entomologists, industry consultants and fieldmen can also help with identification.

Except for Russian wheat aphids, all aphids infesting spring wheat in southern Idaho can carry and transmit the barley yellow dwarf (BYD) virus. Seed-row application of systemic insecticides is unnecessary for prevention of BYD in early-planted spring wheat. Soil-applied insecticides in early-seeded wheat are absorbed and degraded within plant tissues before first aphid flights, making such applications ineffective in controlling aphids. Seed-row applications of systemic insecticides may control aphids and reduce BYD infections in late-seeded spring wheat crops.

English Grain Aphid — The English grain aphid life cycle closely follows wheat growth and development, and overlaps maturity differences between fall- and spring-planted grains. Eggs are deposited in the fall on winter wheat and grasses. Hatching occurs in the spring as temperatures warm. All generations for the rest of the growing season are females that do not lay eggs but give birth to living young. Under favorable conditions, nymphs mature in 6 to 7 days. One mature English grain aphid female may give birth to 40 to 50 nymphs in a 1- to 2-week period. After several generations, winged forms of the insect are produced to disperse the growing population. The insects move from maturing winter cereals and wild grasses to more succulent spring grain crops. In the fall, the English grain aphids migrate back to newly planted fall grain fields, completing the cycle.

English grain aphids can be identified by their black cornicles (dorsal body tubes) and uniform light green to orange body color (Fig. 4). They are oblong-shaped and about ⅛ inch long. English grain aphids are the only aphid species of this general description found infesting grain heads (Fig. 5). English grain aphids cause yield losses by direct feeding. English grain aphids also can spread and transmit the barley yellow dwarf virus from infected fields.

Fig. 4. Adult English grain aphids on a wheat leaf. Arrows point to black cornicles that distinguish the English grain aphid from the rose grass aphid.

Chemical control decisions for the English grain aphid are based on aphid population levels at specific stages of spring wheat growth. Apply insecticides when population reaches 2 to 4 English grain aphids per head or individual tiller at the beginning of flowering, 8 aphids at early kernel development (water stage) or 15 aphids at the early soft dough stage of crop development. Early detection and control minimize losses. Insecticide treatments are not recommended after the mid soft dough stage. Several foliar insecticides are labeled for controlling English grain aphids (Table 20). **ALWAYS read the label before using a registered insecticide.** For more information, consult University of Idaho CIS 778, *Development and Control: The English Grain Aphid on Wheat.*

Fig. 5. Wheat heads containing large populations of green to orange English grain aphids.

Table 20. Guide to contact and systemic insecticides registered for control of aphids on irrigated spring wheat. Strictly follow label directions when using insecticides.

Insecticide[1]	Application rate	Preharvest restrictions
	(a.i. per acre)	
Contact		
parathion	½ lb	15 days to harvest
(Penncap M)	½ lb	15 days to harvest or grazing
malathion	1 lb	7 days to harvest or grazing
Systemic		
dimethoate (Cygon 400)	⅜ lb	14 days before grazing 60 days to harvest
disulfoton (Disyston 15G)	1 lb	75 days to harvest, graze or green chop
(Disyston 8E)	¾ lb	Do not graze 30 days to harvest
phorate (Thimet 20G)	1 lb	28 days before grazing 70 days to harvest

Fig. 6. Adult Russian wheat aphid on a wheat leaf.

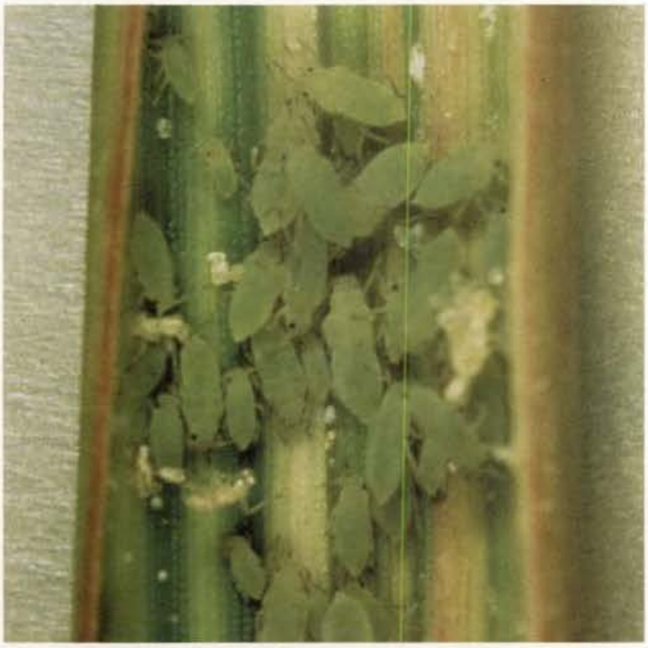

Fig. 7. Leaf streaking and leaf rolling resulting from feeding by a Russian wheat aphid colony in wheat.

Fig. 8. A wheat head distorted by Russian wheat aphid feeding activity.

Russian Wheat Aphid— Russian wheat aphids were first identified in the United States in the spring of 1986, and in Idaho wheat fields during the summer of 1987. Russian wheat aphids have subsequently spread to all wheat-producing areas of the state. Hosts for Russian wheat aphids include wheat, barley, triticale and several grass species. Its potential to damage irrigated spring wheat is not known.

Russian wheat aphids are light green in color, elongate and spindle-shaped (Fig. 6). Cornicles are very short and not noticeable. Antennae are very short compared to most other aphid species. A projection above the tail gives Russian wheat aphids a two-tailed appearance.

Infestations can spread rapidly. Large numbers of aphids are produced in colonies inside rolled leaves. Russian wheat aphids secrete a toxin that causes white or purple streaking on the leaves (Fig. 7). Heads of infested plants may become twisted and distorted or may not emerge (Fig. 8). As the colonies become crowded or the plant declines, wingless aphids move to neighboring plants. Winged forms may be produced that will migrate to new fields. Infestations are more easily identified by the characteristic damage caused by Russian wheat aphid feeding. Purple discoloration of the foliage is more common in cool weather while white streaks and leaf rolling are prominent in warm weather.

Chemical control decisions for Russian wheat aphid are based on infestation levels from crop emergence to the milk stage of kernel development. Insecticides should be applied when more than 10 percent of the spring wheat plants are infested between emergence and flowering stages of growth, or if more than 20 percent infested plants occur after flowering and before the milk stage of kernel development. From soft dough to maturity, chemical control provides little to no benefit and is not recommended. Early detection and control minimizes losses. Several contact and systemic insecticides are labeled for controlling Russian wheat aphids (Table 20). **ALWAYS read the label before using a registered insecticide.** Consult University of Idaho CIS 817, *Russian Wheat Aphid,* for more information.

Fig. 9. Greenbug adult and nymphs. Note dark green stripe on back of adult aphid.

Greenbugs — Greenbugs are short, oblong-shaped aphids with lemon green body color and a dark green stripe that often runs along the back of the abdomen (Fig. 9). Unlike Russian wheat aphids, greenbugs have pale green cornicles with dark tips that do not extend beyond the cauda or tail of the abdomen. Antennae are about ¾ of the body in length. Greenbugs probably overwinter as eggs in southern Idaho but may overwinter as adults in protected locations during mild winters.

Greenbugs live on a variety of cereal crops and grasses throughout the year. Greenbugs injure spring wheat by direct feeding in large numbers, injection of a toxic saliva or by transmitting the BYD virus. Dense colonies form on both upper and lower leaf surfaces, becoming more abundant near heading. Yellow to brown necrotic spots are often caused by toxins secreted during feeding by the insects.

Greenbugs are less likely to damage spring wheat than fall-planted wheat crops. Greatest potential for damage will occur for late-planted spring wheat crops or during years when exceptionally mild winters allow large adult greenbug populations to overwinter and begin feeding early on emerging plants.

Chemical control recommendations for greenbugs suggest insecticide applications when 25 aphids per tiller, stem or head occur on wheat plants sampled before the soft-dough stage of crop development. Contact and systemic insecticides registered to control English grain aphid and Russian wheat aphid are labeled for controlling greenbugs in irrigated spring wheat (Table 20). **ALWAYS read the label before using a registered insecticide.**

Wireworms

Wireworms (*Limonius* and *Ctenicera* species) are beetle larvae (Fig. 10) that feed on the underground portions of living plants. Wireworms injure wheat by devouring seed, by cutting off underground stems and by boring into larger stems and permitting other soilborne pathogens to attack the wounded plant tissue. Usually little wireworm injury occurs in spring wheat following potatoes or sugarbeets.

Serious wireworm injury can occur where spring wheat follows grass or pasture. Commercial seed treatments containing lindane are effective in controlling wireworms.

Fig. 10. Wireworm larvae consume seed, sever below ground stems and severely damage older spring wheat plants.

Diseases

Disease control in irrigated spring wheat depends on preventive measures. Unlike many weed and insect problems, chemical controls are either not available or not economical for most wheat diseases after infection has occurred. Crop rotations that reduce inoculum levels, early seeding dates, disease-free certified seed and disease resistant varieties reduce the impact of disease on spring wheat production.

Irrigated spring wheat in Idaho is susceptible to at least 20 diseases. Fortunately, most crops are impacted by no more than 2 or 3 diseases in a season. The most commonly encountered diseases affecting irrigated spring wheat include barley yellow dwarf, black chaff, common root rot, foliar rusts and take-all. More detailed descriptions and recommended controls of these diseases are in the *Compendium of Wheat Diseases*, APS Press, The American Phytopathological Society, St. Paul, MN 55121, and the most recent edition of *Pacific Northwest Plant Disease Control Handbook* published annually by the University of Idaho, Oregon State University and Washington State University.

Barley Yellow Dwarf

Barley yellow dwarf (BYD) is caused by a virus transmitted by several cereal aphids. Aphids acquire the BYD virus by feeding on infected grain crops or on range and lawn grasses that serve as alternate hosts for the virus. In Idaho, the bird cherry-oat aphid, corn leaf aphid, English grain aphid, rose grass aphid and greenbug can carry and transmit the virus from infected plants. The Russian wheat aphid has not been observed to transmit the BYD virus in the United States. Early-seeded winter wheat is more commonly affected, but late-seeded spring wheat crops can also be devastated by BYD. Yield losses are usually proportional to the percentage of plants infected by the virus.

The principle symptoms of BYD in irrigated spring wheat include leaf discoloration in shades of yellow, red and/or purple (Fig. 11), reduced root growth and general stunting (Fig. 12). Plants infected before the 4- to 5-leaf stage are often severely stunted and may not head. Disease symptoms and yield losses are less severe when infection is delayed to more advanced stages of crop development. Late infections occurring after the boot stage produce few or no symptoms of the disease and may not impact spring wheat yields.

Seeding early is the most effective means of avoiding BYD in spring wheat. Early seeding permits the crop to emerge and develop before spring flights of virus-transmitting aphids occur. Avoid moisture stress and N deficiencies to ensure rapid growth and reduce the severity of BYD in infected crops. Spring wheat varieties resistant to BYD are not available in Idaho. Systemic insecticides can be used to control virus-transmitting aphids during early stages of wheat growth where seeding dates are delayed (see Insect Pests-Aphids). Consult University of Idaho CIS 672, *Barley*

Fig. 11. BYD symptoms in wheat initially appear as chlorotic blotches scattered on the leaf. Later, the leaf tips may be yellow or reddish purple.

Fig. 12. Stunted, chlorotic plants in a small area surrounded by taller, healthy plants are an indication of barley yellow dwarf.

Fig. 13. (a) Left, black chaff infected wheat seedlings showing water-soaked spots on leaves. (b) Right, black chaff infected leaf showing necrotic regions surrounded by a lime-green halo.

Yellow Dwarf, for more information on BYD in irrigated spring wheat.

Black Chaff

Black chaff (*Xanthomonas campestris* pv. *translucens*) is a bacterial disease that attacks leaves, stems and heads of spring wheat particularly when grown under irrigated conditions. Black chaff symptoms on leaves appear initially as watersoaked streaks and spots (Fig. 13a) that eventually turn brown and are occasionally surrounded by a lime-green halo (Fig. 13b). Dark purple lesions with light yellow centers often form in the stem region between the head and flag leaf collar.

Black chaff causes dark blotches on the glumes of infected heads (Fig. 14), indicative of the disease's name. Infected awns develop a striped ''barber pole'' appearance caused by alternating bands of darkened diseased and healthy lighter-colored tissue. Splashing water from rain or irrigation spreads the black chaff bacteria from diseased to healthy plants during wheat production. Black chaff bacteria are spread between seasons on infested seed and plant residues.

No chemicals currently control black chaff either on infested seed or in the field. Use disease-free seed and avoid seeding spring wheat into grain stubble infested by black chaff bacteria. Commercial spring wheat seed lots can be assayed for black chaff infestation by the University of Idaho Seed Pathology Laboratory at Moscow, Idaho. More information on black chaff is available in University of Idaho CIS 784, *Black Chaff of Wheat and Barley.*

Fig. 14. Characteristic darkening of wheat glumes infected with black chaff bacteria.

Black Point

Black point describes the discolored appearance of harvested grain infected by fungi during kernel development (Fig. 15). Kernel infection is favored by humid field conditions (>90 percent relative humidity) while kernel moisture content exceeds 20 percent. Many fungi can cause black point, including *Alternaria*, *Cladosporium*, *Fusarium* and *Bipolaris* (syn. *Helminthesporium*) species. Black point is more prevalent under irrigated than under dryland conditions.

Kernels darkened by black point fungi are considered damaged by USDA Federal Grain Inspection Service standards used to determined commercial market grades. Only 2 percent and 4 percent damaged kernels are permitted in U.S. No. 1 and No. 2 grades, respectively. Severe black point infections can also reduce seed germination levels. Black point damage can increase for infected grain stored under humid conditions. Use resistant varieties (Table 3), avoid overirrigation and store grain under dry conditions to minimize black point. Consult University of Idaho CIS 536, *Aeration for Grain Storage*, for recommendations on attaining best grain storage conditions.

Common Bunt

Common bunt (syns. stinking smut, covered smut) is caused by the fungi *Tilletia tritici* and *T. foetida*. Spores of these fungi infesting spring wheat seed germinate in the soil at temperatures of 40° to 60°F and infect the germinating seedlings before emergence. Infected plants may be somewhat stunted but are difficult to identify before heading. The kernels of bunted heads are replaced with darkened sori or bunt balls containing black spores with a characteristic fishy odor. Both healthy and diseased heads can occur on the same plant, and both healthy and bunted kernels can occur in the same head.

Common bunt can reduce grain yield and crop quality. Smutted grain retains the pungent, fishy odor and is discounted in commercial markets. The use of resistant varieties, clean seed and chemical seed treatments have nearly eliminated common bunt in Idaho. Regional breeding programs are no longer screening for common bunt resistance, and most spring wheat varieties are susceptible to common bunt. Commercial seed treatment formulations containing either carboxin or PCNB are effective in controlling common bunt (Table 21).

Common Root Rot

Common root rot is caused by a complex of soilborne fungi including *Bipolaris* (syn. *Helminthosporium*) and *Fusarium* species. Damping off (sudden death) of emerging seedlings can occur, but seedling blight and leaf infections caused by these fungi are rare in Idaho. Infected plants appear stunted, have reduced root areas and exhibit decay of the crown area. Common root rot is favored by soil compaction that restricts spring wheat root growth.

Control of common root rot is achieved primarily by cultural practices. Avoid soil compaction. Adequate N and P levels encourage vigorous root and shoot growth, enabling plants to resist or tolerate infection. Early seeding dates and proper seeding depths permit uniform germination and emergence under cooler soil temperatures that reduce common root rot infections. Rotation with non-cereal crops and control of grassy weeds can reduce common root rot soil inoculum levels.

Post-emergent fungicides are not available for control of common root rot. Commercial seed treatment fungicides that prevent seed rot and damping off by these fungi offer varied protection from common root rot (Table 21). Seed treatment formulations of the systemic fungicide imazalil are registered for control of common root rot on spring wheat. **ALWAYS read the label of a registered fungicide before use.**

Ergot

Ergot is caused by the fungus *Claviceps purpurea* and affects wheat, barley, rye, triticale and numerous grass species. The ergot fungus infects spring wheat during flowering. Infected florets develop dark, hard, hornlike structures called sclerotia instead of normal kernels (Fig. 16). Ergot sclerotia contain toxic alkaloids and reduce the value of grain sold for either food or

Fig. 15. Soft white wheat kernels discolored by black point fungi.

Table 21. Guide for seed treatment fungicides registered for use on irrigated spring wheat in Idaho. Strictly follow label directions when using commercial formulations.

Fungicide	Common seed rot	*Pythium* root rot	Common root rot	Common bunt	Loose smut
Contact					
captan	X[1]				
etridiazole	X			X	
maneb	X			X	
mancozeb	X			X	
PCNB	X			X	
TCMTB	X			X	
thiram	X			X	
Systemic					
carboxin	X			X	X
imazalil	X		X		
metalaxyl		X			

[1]X indicates fungicidal activity on disease pathogens.

feed. Sclerotia returned to the soil with straw and chaff residues persist between cropping seasons and perpetuate the disease.

Ergot sclerotia germinate near the soil surface during late spring to produce ascospores. Ascospores spread by wind and rain infect the open florets of flowering wheat. The chances of infection are increased by wet, cool weather that prolongs flowering, and by conditions such as frost that cause floret sterility. Infected florets initially exude a sticky honeydew containing spores (conidia) that are further spread to other florets by wind, rain and attracted insects. Infected florets eventually develop into sclerotia.

Use clean spring wheat seed that does not contain ergot sclerotia. Tillage operations that bury sclerotia 2 or more inches deep will reduce ascospore release. Control grassy weeds and rotate cereals with nongrass crops to reduce inoculum levels. Mow or burn grasses surrounding spring wheat fields before flowering. Dirkwin soft white spring wheat is more susceptible to ergot than other spring wheat varieties. For more information on ergot, consult University of Idaho CIS 145, *Ergot — A Loser for Grain Growers and Livestock Owners.*

Rusts

Rust fungi (*Puccinia* species) occur in all wheat-producing regions of Idaho and occur with greater frequency than other foliar diseases. Named for the dry, dusty, rust-like pustules that erupt through infected plant tissues, they are probably the most destructive wheat diseases known.

Three distinct rust diseases occur on irrigated spring wheat: stripe rust (*P. striiformis*), leaf rust (*P. recondida* f.sp. *tritici*) and stem rust (*P. graminis* f.sp. *tritici*). All three rust pathogens have complex life cycles requiring living hosts to perpetuate themselves. All three rust diseases have two distinct development stages on wheat — a "red" or "uredial" stage producing spores (urediaspores) infecting other wheat plants followed by a "black" or "telial" stage producing spores not infectious to wheat. Urediospores can be carried long distances by wind, spreading these diseases over large production areas. Rust spores usually do not overwinter under Idaho conditions, but are readily blown in from other regions. Use of resistant varieties, control of alternate hosts and use of foliar fungicides are control measures for managing rust diseases in irrigated spring wheat. Early detection and control of rust minimize impacts on spring wheat yields and crop quality.

Fig. 16. Ergot sclerotia among normal soft white wheat kernels.

Stripe Rust — Stripe rust is the most common cereal rust disease in Idaho, attacking wheat, barley, rye, triticale and several grass species. Oats are immune to stripe rust. Clusters of yellow pustules form long, narrow stripes on leaves (Fig. 17a), leaf sheaths, glumes and awns. Infectious urediospores are released from the yellow pustules. Stripe rust development on wheat is favored by cool, mild temperatures, intermittent spring rains and heavy dews interspersed with bright sunny days. Stripe rust persists through the summer on volunteer cereal grains and late season grasses. The disease overwinters on grasses, infected fall-planted wheat and volunteer grains. Stripe rust urediospores can survive during unusually warm winters.

Stripe rust reduces spring wheat yields, test weights and grain protein levels. Use spring wheat varieties resistant to stripe rust (Table 3). Where varietal resistance has failed or is not available, foliar fungicides are registered for control of stripe rust on irrigated spring wheat (Table 22). Contact fungicides are less expensive per application than systemic fungicides, but may require multiple applications for season-long control. **ALWAYS read the label before using a registered fungicide.**

Leaf Rust — Leaf rust attacks wheat, rye and triticale. Leaf rust will occasionally occur on barley, while oats appear immune to this disease. Leaf rust appears as small, oval-shaped, orange-red pustules on the upper surface of leaves and leaf sheaths (Fig. 17b). Leaf rust pustules form in random patterns and do not cluster in parallel stripes like stripe rust. Leaf rust also persists through the summer months on volunteer grains, but development is favored by warmer, dryer weather. Leaf rust usually does not appear until late in the cropping season. Significant yield losses can occur when leaf rust infects young plants or when late-maturing susceptible varieties are grown.

Many spring wheat varieties are resistant to leaf rust (Table 3). Foliar fungicides effective against stripe rust also are registered for control of leaf rust (Table 22). Since leaf rust usually occurs late in the growing season, fungicides are rarely needed, and the cost of application should be judged against the potential economic benefit.

Stem Rust —Stem rust attacks wheat, rye, triticale and barley. Stem rust first appears as oval reddish-brown pustules. All aerial portions of spring wheat are susceptible. Pustule color is similar to leaf rust, but occurs with greater frequency on leaf sheaths and stem tissue. Stem rust pustules develop on both surfaces of infected leaves and possess very ragged edges compared to leaf rust pustules (Fig. 18). The life cycle of the stem rust fungus is completed on common barberry (*Berberis vulgaris* and *B. canadensis*) that serves as an alternate host.

Stem rust is favored by warm weather and typically develops late in the growing season. Stem rust is rarely a major economic pest of irrigated spring wheat in Idaho. Many spring wheat varieties are resistant to stem rust (Table 3). Foliar fungicides effective against stripe and leaf rusts will also control stem rust (Table 22).

Fig. 17. (a) Left, yellow pustules of stripe rust forming long stripes on spring wheat leaves. (b) Right, leaf rust pustules on wheat.

Fig. 18. Stem rust pustules erupting on leaf and leaf sheath surfaces. Note ragged pustule edges.

Powdery Mildew

Powdery mildew (*Erysiphe graminis* f.sp. *tritici*) is a fungus that attacks the foliage and heads of irrigated spring wheat. White, cottony patches of the fungus initially form on the upper surfaces of lower leaves that can spread to all aerial portions of the plant (Fig. 19). These patches turn dull gray or brown with age and develop fruiting bodies that appear as dark specks. Powdery mildew damages plants by using plant nutrients, destroying leaf surfaces, reducing plant photosynthesis and increasing plant respiration and transpiration rates. Dense stands, heavy N fertilization, lush growth, high humidity and cool temperatures favor disease development.

Powdery mildew rarely causes economic losses in irrigated spring wheat in Idaho. Losses associated with powdery mildew infections are usually not great enough to warrant chemical control. Systemic foliar fungicides such as Bayleton and Tilt are registered for the control of powdery mildew (Table 22), but their use is not cost-effective unless they are used to control other diseases such as stripe rust. Crop rotation and clean cultivation can reduce powdery mildew inoculum associated with crop residue. Abundant airborne spores and warm, moist conditions often limit the benefits of cultural control practices, however. Some newer spring wheat varieties are resistant to powdery mildew (Table 3).

Take-All

Take-all (*Gaeumannomyces graminis* var. *tritici*) is a soilborne disease that affects irrigated wheat produced under recrop conditions. The take-all fungus infects the crown region and roots of the plant. Severely infected plants are stunted, ripen prematurely and exhibit distinctly bleached heads. Pulling a severely infected plant reveals crown rot, severely pruned feeder roots and a shiny black appearance of the lower stem surface (Fig. 20). Greatest yield losses due to take-all often occur in the second, third and fourth years of continuous wheat or barley production.

Fig. 19. Patches of powdery mildew on leaves of spring barley. Patches eventually turn grey or brown with fruiting bodies appearing as dark specks. Symptoms are similar on wheat foliage.

Fungicides are not available for control of take-all. Rotation with non-host crops such as alfalfa and other broadleafs is an effective means of control. A 1-year break in wheat cultivation is sufficient to reduce soilborne inoculum levels but will not eliminate the take-all fungus. Tillage operations that fragment crop residues and encourage decomposition limit survival of take-all fungus in the soil.

Early seeding dates reduce the incidence of take-all. Adequate N fertility is important to encourage root and crown development, but the N form used can influence infection levels. Nitrate-based fertilizers favor take-all infection more than ammonium or urea fertilizers. Fertilizers containing chloride (i.e. ammonium chloride, potassium chloride) have reduced take-all in other wheat producing regions. Similar chloride effects on take-all have not been demonstrated with spring wheat in Idaho.

A phenomenon called "take-all decline" can reduce losses from this disease. After increasing in severity for the first 2 to 5 consecutive years of wheat production, soil inoculum levels and take-all severity decline in subsequent crops. The decline is a form of biological control suspected to be caused by a buildup of microorganisms antagonistic to the take-all pathogen. Take-all decline will persist only if continuous wheat crops are grown, and the field is not rotated to nonhost crops.

Wheat Streak Mosaic

Wheat Streak Mosaic (WSM) is caused by a virus transmitted by the wheat curl mite (*Aceria tulipae*). These mites are very small (0.3 mm long), white and cylindrically shaped (Fig. 21). Detection and identification of the mite usually require magnification with a hand lens. Corn and certain grasses also are hosts for the WSM virus and wheat curl mite, but wheat is the principle host for the virus. Mites are dispersed from plant to plant and from field to field by wind. The impact of WSM is usually less on spring wheat than on winter wheat.

Table 22. Guide for foliar fungicides registered for use on irrigated spring wheat in Idaho. Strictly follow label directions when using commercial formulations.[1]

Fungicide	Rates	Foliar rusts: Stripe	Foliar rusts: Leaf	Foliar rusts: Stem	Powdery mildew
	(a.i./acre)				
Contact					
mancozeb (Dithane, Manzate and Penncozeb)	1.6 lb		X		
Systemic					
triadimefon	1 to 3 oz				X
(Bayleton)	2 to 4 oz	X	X	X	
propiconazole (Tilt)	1.8 oz	X	X	X	X
benomyl (Benlate)	0.125 to 0.25 lb		X		X
+	+				
Manzate 200	0.8 to 1.6 lb				

[1]X indicates registered for use of disease control within the range of labeled application rates.

Symptoms of WSM include stunting and parallel green-yellow streaks on leaves. Leaf margins are often rolled toward the midrib by the feeding activity of the mites. Symptoms are more dramatic at warmer temperatures. Heads that form may be totally or partially sterile. Because the mite is dispersed by wind, symptoms are initially seen near field margins. Conditions that benefit the spread and development of BYD also benefit the spread and development of WSM. Yield losses from WSM infections in spring wheat are often compounded by the presence of BYD.

Early spring seeding dates reduce the likelihood of WSM in irrigated spring wheat by allowing crop growth during periods too cool for mite activity. Management practices that encourage rapid spring wheat growth minimize the impact of WSM. The WSM virus and wheat curl mite are often harbored between seasons in volunteer wheat. Both virus inoculum levels and mite populations are reduced by control of volunteer grains. Butte hard red spring wheat has some tolerance to the WSM virus.

Nematodes

Nematodes are very small (Fig. 22), unsegmented roundworms that inhabit soil and water. Most nematodes are nonparasitic, but two species feed on the roots of spring wheat in Idaho. Nematode feeding causes direct plant injury and exposes developing roots to soilborne diseases that normally have minimal impact on spring wheat crops. The economic impact of these nematodes on spring wheat is not fully known.

Cereal Cyst Nematode — The cereal cyst nematode (*Heterodera avenae*) was first identified in Oregon in 1972 and has since been identified in southern Idaho. Eggs contained in cysts may lie dormant in soil for many years. Cysts are spread in windblown soil, on contaminated equipment, in waste irrigation water and on infested seed potato tubers. Greatest damage occurs on spring wheat grown in sandy soils where large populations of cereal cyst nematodes exist. Where cereal cyst nematode damage has occurred, wheat and other small grains should be grown as infrequently as possible in rotation with broadleaf crops. Grassy weeds such as wild oats and ryegrass can sustain cereal cyst nematodes and should be controlled. Chemical nematicides are effective but not economical for control of the cereal cyst nematode.

Columbia Root Knot Nematode — The Columbia root knot nematode (*Meloidogyne chitwoodi*) parasitizes wheat but is not known to cause economic losses in irrigated spring wheat in Idaho. A closely related species, the northern root knot nematode (*M. hapla*), also occurs in Idaho but does not reproduce on wheat. Chemical nematicides are not recommended for controlling root knot nematodes in irrigated spring wheat unless their application benefits other rotation crops.

Harvesting

Proper adjustment and operation of the combine reduces harvest losses. Adjust the combine initially to specifications provided by the manufacturer, and field check for grain loss out the back of the combine. Depending on variety, approximately 16 to 20 kernels per square foot on the ground represents a 1 bushel per acre loss. Adjust air speed to separate chaff from grain without blowing grain out the back of the combine. On cylinder-type combines, adjust cylinder speed and concave clearance to thresh grain free without cracking. Periodic field checks should be made during harvest to adjust for changing moisture content of the straw and grain.

High-yielding irrigated spring wheat, including newer semi-dwarf varieties, commonly produce 5 to 7 tons of straw per acre. Ground speed, swath width and header height can be adjusted to control the amount of material entering the cylinder for best grain separation and to avoid plugging.

Straw Management

Combine Residue Distribution

Uniform distribution of the combine residue at harvest is advantageous. High concentrations of straw and chaff interfere with subsequent tillage and planting operations and create a poor environment for plant growth.

Fig. 20. Pruned roots and crown rot symptoms of take-all on wheat. Note shiny black appearance of lower stems.

Uniform residue distribution is especially important for no-till or minimum tillage seeding of the following crop. The effects of heavy straw and chaff rows have also been observed under conventional tillage. For more information about residue management in cereal production systems, refer to PNW 297, *Uniform Combine Residue Distribution for Successful No-till and Minimum Tillage Systems*.

Installation of commercial chaff and straw spreaders or modifications to the existing spreader can minimize residue distribution problems. Residue distribution by both cylinder and rotary type combines, with and without straw and chaff spreaders is shown in Fig. 23. Total residue was 4.8 tons per acre including harvested straw and chaff (2.7 tons per acre) and uncut stubble (2.1 tons per acre). Standard cylinder combines with no alteration (factory run) produce uneven residue distribution patterns (Fig. 23a). Residue distribution ranged from 9.0 tons per acre directly behind the combine to 2.1 tons per acre (only the uncut stubble) near the outer edges of the header. Chaff comprises 65 percent of the residue directly behind the combine. A straw-chopper reduces straw length but does little to improve residue distribution. A cylinder combine with a commercial chaff spreader distributes straw and chaff more uniformly. Chaff thrown beyond the header width causes overlaps, with higher residue levels near the joining edge of the swath. Adjusting the chaff spreader speed corrects this problem.

Standard rotary combines with center exits and no residue spreading attachments have a distribution pattern (Fig. 23b) similar to that produced by standard cylinder combines without attachments (Fig. 23a). Using a spreader distributed the residue more uniformly, but chaff and straw thrown beyond the header width creates a secondary peak in residue from overlaps with the adjoining swath. Lowering the flails, adding flail bats and increasing flail rotation speed on rotary combines provides a uniform distribution of residue. Growers can either modify their own flail system or purchase relatively low-cost commercial modifications.

Fig. 21. Wheat curl mites.

Growers can either modify their own flail system or purchase relatively low-cost commercial modifications.

Residue Distribution and Nitrogen Availability

High concentrations of straw and chaff in combine rows reduce availability of nutrients, particularly N. Carbon/nitrogen (C/N) ratios of 50 or less are needed for efficient decomposition of crop residue by soil microbes. Cereal residues typically possess C/N ratios of 100 to 150. Additional N is required for microbial decomposition, coming from available soil N or from N fertilizer. Nitrogen fertilizer applied to correct N shortages in combine rows exceeds nitrogen requirements between rows.

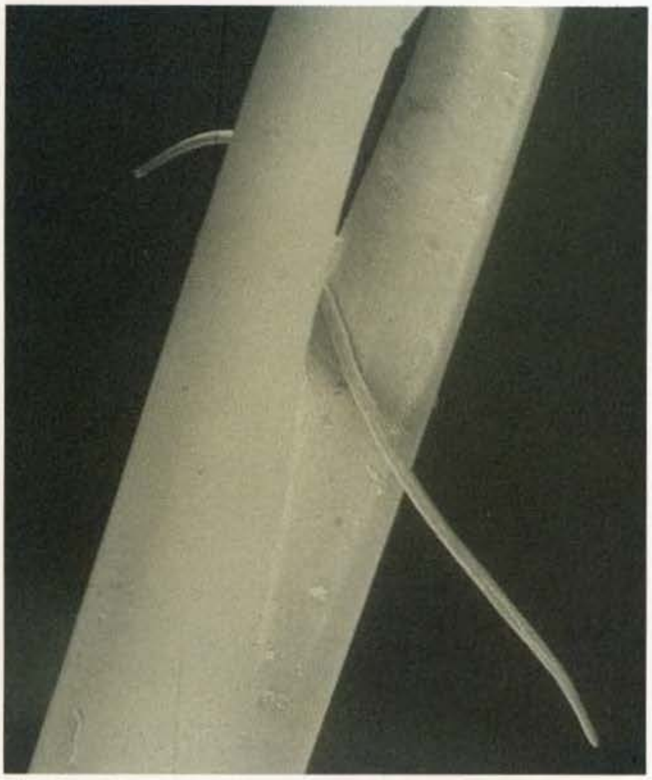

Fig. 22. Adult root-knot nematode passing through the eye of a needle.

Uniform residue distribution can maintain more uniform field N levels. Table 23 compares residue distribution to areas of potential N shortage using standard and modified flail systems on a 24-foot rotary combine. With the standard factory flail system, residues across the header swath ranged from 2.4 tons per acre in the outer 4 feet to 7.3 tons per acre in the middle 12- to 16-foot section. Estimated N shortages from microbial decomposition in the middle 12- to 16-foot section (51 lb N/acre) were three times higher than N shortages in the outer 4 feet (17 lb N/acre) of the swath. With a modified flail system, the largest difference in residue and N shortage was 1.1 tons of straw and 8 pounds of N per acre, respectively.

Production Costs and Budgeting

Analyzing costs and budgeting expenditures are important tools for evaluating short and long term returns from irrigated spring wheat production. If a proposed management change is shown to be profitable and generates sufficient revenue to meet additional cash requirements, then investment in the proposed change may be acceptable. A change that is not profitable or does not provide adequate cash flow should be rejected. Therefore, cost analysis and budgeting are techniques for evaluating operational adjustments before actually implementing them.

Enterprise budgets published by the University of Idaho are based on production practices considered typical on well-managed farms within an area the budget represents. Information is collected from farmers, Extension agents, Extension specialists and others pertaining to cultural practices, type and quantity of inputs and the expected level of production. Generating enterprise budgets requires realistic assumptions about future inputs, production costs and prices. Table 25 summarizes the assumptions used to develop the irrigated spring wheat budget reviewed in Table 24. More detailed enterprise budgets are available from the Department of Agricultural Economics and Rural Sociology at the University of Idaho.

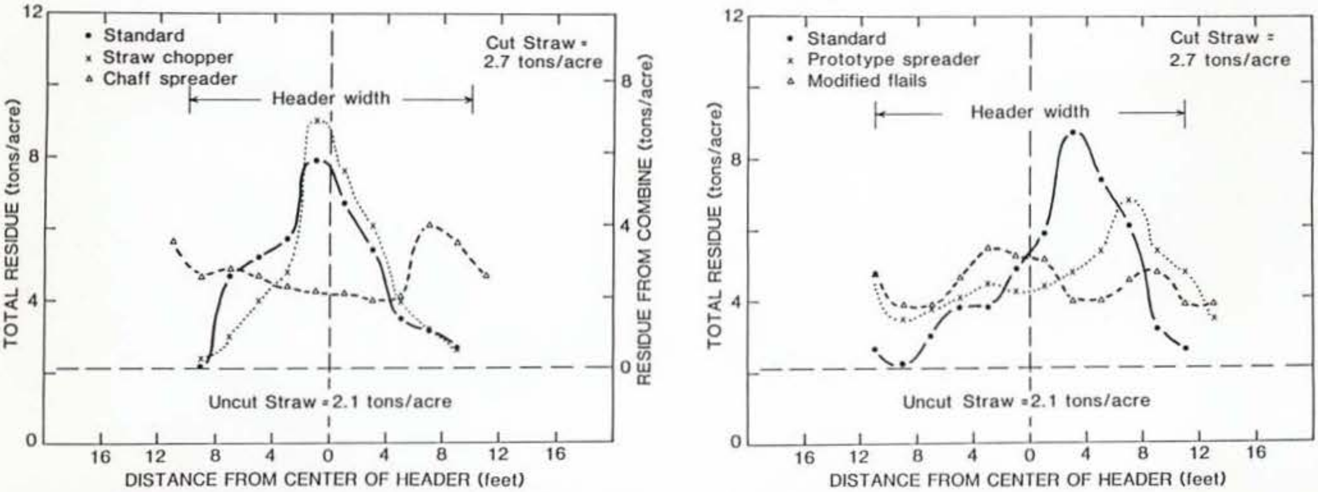

Fig. 23. Residue distribution by cylinder (a) left, and rotary (b) right, combines equipped without and with residue spreading attachments.

Budget Analysis

Table 24 summarizes gross receipts from production, variable costs and fixed costs for irrigated spring wheat in southcentral Idaho. The first section represents gross receipts from production (price × quantity = total value) estimated at $330 per acre . The second section lists variable costs, estimated at $145.78 per acre. The final section shows fixed costs per acre, including insurance, taxes, depreciation, interest on owner equity or long-term loans, certain repairs and long-term cash or fixed leases. Depreciation is calculated using the straight line method. The assumed interest rate is 12 percent for borrowing intermediate term capital. Interest rate is calculated on average investment: [(new cost + salvage value)/2] × 12 percent. Other items such as property taxes and insurance are calculated using current tax and insurance rates. The calculation for property tax would be (market value × tax rate)/hours used annually, and for insurance, simply average investment per hour used × insurance rate. The estimated fixed cost is $184.57 per acre.

Total costs include the sum of total variable and total fixed costs. These are subtracted from gross receipts to obtain net returns to risk and management. Net returns are compensation to the producer for management and the risk assumed in producing the crop.

Breakeven Analysis

Breakeven levels can show prices or quantities of a product needed to cover operating, fixed and total costs. To calculate breakeven prices, the producer must know yields and costs. This enterprise used 110 bushels per acre as the level of production for planning purposes (Table 24). Operating costs are estimated at $145.78 per acre (pre-harvest costs are $133.99 and harvest costs are $11.79 per acre). The breakeven price (BE_p) needed to cover variable costs is calculated as follows:

$$
\begin{aligned}
BE_p &= \text{Variable costs/Yield quantity} \\
&= \$145.78/110 \text{ bushel} \\
&= \$1.33 \text{ per bushel}
\end{aligned}
$$

Breakeven price would be $1.68 per bushel to cover fixed costs and $3.00 per bushel to cover all costs of production. This information can help the producer formulate spring wheat marketing and management plant. For example, an offer of $2.50 per bushel for the wheat crop would leave the grower about $1.17 for fixed costs and returns to management. With fixed costs of $1.68 per bushel, the grower would lose $0.51 per bushel.

If a grower has contracted wheat at some price level, the yield necessary to cover production costs can be calculated. Assuming a contract price of $3 per bushel, the breakeven quantity (BE_q) in bushels per acre is calculated as follows:

$$
\begin{aligned}
BE_q &= \text{Variable costs/Contracted price} \\
&= \$145.78/\$3 \text{ per bushel} \\
&= 48.6 \text{ bushels per acre}
\end{aligned}
$$

The grower needs to produce 49 bushels per acre at $3 per bushel to cover operating costs, 62 bushels per acre to cover fixed costs or 110 bushels to cover all costs of production.

Risk Analysis

Wheat prices often vary from month to month during a given year, and wheat yields vary from year to year. Yield and price variation will impact gross revenue (price × quantity) and returns above operating, fixed and total costs. Commercial enterprises susceptible to these price or yield variations would show negative returns over costs when gross revenue declines by some percentage figure. Calculating that percentage figure helps determine how susceptible the profitability of the operation is to risk.

Over the past 10 years, average annual spring wheat prices in Idaho have ranged from $2.36 to $3.64 per bushel. In 8 out of 10 years, the average market price exceeded the breakeven price to cover total costs of production ($3.00/bu) calculated from Table 24. The breakeven price needed to cover variable costs ($1.33/bu) was exceeded every year. Not too much price risk occurs over the 10-year period.

But what about the short run? Assuming wheat prices vary 15 percent above or below the $3.00 planning price used in Table 24, the minimum price would be $2.55 and the maximum price would be $3.45 per bushel. At $2.55 per bushel, gross revenue would be $280.50 per acre (110 bushels times $2.55 per bushel). Assuming the same costs as presented in the base budget, and a 15 percent lower price, income above variable costs would decline from $233.71 at $3.00 per bushel to $134.71 at $2.55 per bushel. Returns over all costs would decline from −$0.35 to −$49.86. With a 15

Table 23. Effect of rotary combine flail distribution system on residue amount across the header width and potential nitrogen shortage from microbial tie-up of nitrogen in residue decomposition.

Component	Flail system	Segments across header width in feet: 0 to 4	4 to 8	8 to 12	12 to 16	16 to 20	20 to 24
		(tons/acre)					
Residue	Standard	2.4	3.4	4.4	7.3	6.8	2.9
	Modified[1]	4.4	4.3	5.4	4.6	4.3	4.4
		(pounds/acre)					
Nitrogen shortage	Standard	17	24	31	51	48	20
	Modified[1]	31	30	38	32	30	31

[1]Flail cones lowered, larger flail bats added and rotation speed increased.

Table 24. Enterprise budget for irrigated spring wheat in southern Idaho. Assumptions for developing budget are given in Table 25.

Factor	Unit	Units per acre	Price/cost per Unit	Value or cost	Your value
			($)	($)	($)
Gross receipts from production					
Spring wheat	bushel	110.00	3.00	330.00	______
Total				330.00	______
Variable costs					
Preharvest costs					
Seed	pounds	105.00	0.08	8.92	______
Nitrogen	pounds	100.00	0.25	25.00	______
N application	acre	1.00	4.50	4.50	______
2,4-D amine	quart	0.75	2.25	1.69	______
Avenge	quart	1.50	12.78	19.17	______
Sprayer	acre	1.00	1.00	1.00	______
Crop insurance	acre	1.00	3.50	3.50	______
Machinery	acre	1.00	12.73	12.73	______
Tractors	acre	1.00	5.38	5.38	______
Irrigation	acre	1.00	31.54	31.54	______
Labor (Machinery)	hour	1.94	5.50	10.65	______
Labor (Irrigation)	hour	1.18	4.75	5.60	______
Interest on operating capital	dollar	39.17	0.11	4.31	______
Subtotal				133.99	______
Harvest costs					
Machinery	acre	1.00	7.70	7.70	______
Labor	hour	0.74	5.50	4.09	______
Subtotal				11.79	______
Total variable costs				145.78	______
Fixed costs					
Machinery	acre	1.00	82.90	82.90	______
Tractors	acre	1.00	9.72	9.72	______
Land (net rent)	acre	1.00	91.95	91.95	______
Total fixed costs				184.57	______
Total costs				330.35	______
Net returns to risk				−0.35	______

percent decline in the planning price, the grower fails to cover $49.86 of his fixed costs. Similar values can be calculated for increases in price.

Table 25. Assumptions for developing an enterprise budget for irrigated spring wheat production in southern Idaho.

Factor	Assumption
Yield	Estimated at 110 bushels per acre.
Commodity price	The estimated price of spring wheat ($3) is based on price historical levels and projected short term trends. This price is only an estimate and subject to change. Also consider government payments and premiums when determining actual crop income.
Labor costs	Hired labor for farm operations is valued at $5.50 per hour. Labor costs associated with tractor and machinery are calculated by multiplying annual tractor hours by a factor of 1.1 (1.2 for self-propelled machinery). These factors account for time spent maintaining, lubricating and operating the machinery. Labor cost is determined by multiplying the calculated hours by the labor wage rate.
Custom work	A ground fertilizer application was performed at a cost of $4.50 per acre.
Crop insurance	Estimated at $3.50 per acre
Interest on operating capital	The interest rate used on operating capital is 11 percent and represents both the cost of the operating capital borrowed and the rate of return on equity capital had it been invested in the next best alternative. Total capital requirements are estimated for each of the 12 months budgeted, and converted to an annual basis by summing monthly interest expenses. Interest is charged from the time of input application until the crop is harvested.
Land (net rent)	Net rent represents the minimum return a landowner would accept in return for the privilege of producing on his own land. Also known as an opportunity cost, it is a non-cash item that describes the return foregone because a landowner elects to produce rather than rent his land. Under a typical spring wheat cropshare lease agreement, 33 percent is the landlord share and 67 percent is the tenant share. The landlord pays property taxes, and 33 percent of fertilizer and chemical costs for his share. Net rent in the enterprise budget was based on this 1/3-2/3 crop share arrangement.
Machinery	All machinery and irrigation equipment is valued at current replacement costs. This assumption evaluates the ability of an enterprise to replace current depreciable assets. Replacement costs can reflect either new or used equipment costs, but should be current and within reason.
Irrigation	A center pivot irrigation system without corner catchers is assumed. In a typical landlord-tenant relationship, the landlord furnishes the irrigation equipment and the water. The tenant is responsible for maintainence and operating costs of the system. Consult University of Idaho CIS 577, *Investment Costs for Sprinkler Irrigation;* CIS 578, *Investment Costs for Gravity Irrigation Systems,* and CIS 579, *Investment Costs for Center Pivot Irrigation Systems.*

The sensitivity of returns to price and yield fluctuations of $2.50 to $3.50 per bushel and 90 to 130 bushels per acre, respectively, are summarized in Table 26. Generally speaking, negative returns in Table 26 indicate that the enterprise is susceptible to price and/or yield risk. More care must be taken with marketing and management of these enterprises.

Table 26. Sensitivity analysis of net returns for irrigated spring wheat production in southcentral Idaho where price varies from $2.50 to $3.50 and yield varies from 90 to 130 bushels per acre. Production costs cited in Table 25 are used to calculate net returns.

	Price of spring wheat per bushel				
Yield	$2.50	$2.75	$3.00	$3.25	$3.50
(bu/acre)			($)		
Net return after variable costs					
90	79.21	101.71	124.21	146.71	169.21
100	104.21	129.21	154.21	179.21	204.21
110	129.21	156.71	184.21	211.71	239.21
120	154.21	184.21	214.21	244.21	274.21
130	179.21	211.71	244.21	276.71	309.21
Net return after fixed costs					
90	40.43	62.93	85.43	101.93	130.43
100	65.43	90.43	115.43	140.43	165.43
110	90.43	117.93	145.43	172.93	200.43
120	115.43	145.43	175.43	205.43	235.43
130	140.43	172.93	205.43	237.93	270.43
Net return to risk					
90	−105.36	−82.86	−60.36	−31.86	−15.36
100	−80.36	−55.36	−30.36	−5.36	19.64
110	−55.36	−27.86	−0.36	27.14	54.64
120	−30.36	−0.36	29.64	59.64	89.64
130	−5.36	21.14	59.64	92.14	124.64

Summary

Proper field selection, seedbed preparation and planting practices and variety selection prevent many problems associated with irrigated spring wheat production. Plant early, test soil to determine nutrient requirements and use clean seed of high germination and vigor for optimum production. Routinely monitor fields for developing weed, disease and insect problems, so effective control measures can be implemented early.

Timing of all production operations, especially irrigation, is crucial for profitable irrigated spring wheat production. Plan ahead for spring wheat production by developing a production guideline and schedule of operations before planting the crop. Examine short and long term benefits with an enterprise budget system. Time spent in planning will always provide maximum returns on investments.

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